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Institute and Related Activities

A Graphic Method for the Exact Solution of Transmission Lines

BY COLLIS H. HOLLADAY
Associate, A. I. E. E.
Southern California Edison Company

Review of the Subject.—*There seems to be a popular superstition among engineers that the voltage and current relations at different points in a transmission line are peculiar and are not governed by Ohms law. This idea is not true. A transmission line is governed by Ohms law just as is any other alternating-current circuit containing resistance inductance and capacity. The only difference from an ordinary circuit is that in a transmission line we must make a correction for the effect of distributed constants.*

If we change the current flowing through a line by an amount I, there will be a voltage change equal to I Z between the two ends of the line. The Z in this case, however, is corrected for the distributed constants of the line. The hyperbolic formula which are so widely coming into use, since Doctor Kennelly has given us tables of complex hyperbolic functions, are merely short methods of determining this Z as well as certain other constants which we must use.

If we start with a certain voltage Eg at the generator; on open circuit, we will have a slightly higher voltage at the receiver, due to the line capacity drawing a leading current through the inductance. As we load the line with a lagging current this voltage rise is counteracted by the impedance drop.

In a similar manner the generator current is equal to the vector sum of the charging current, and the load current which has been multiplied by a constant.

It is possible to express these relations by a vector diagram. Drawing a voltage and current diagram on the same sheet and to suitable scales offers a very convenient method of calculation. From such a diagram it is possible to read directly power and power factor as well as condenser kv-a. necessary for voltage regulation.

CONTENTS

THE purpose of this paper is to describe a quick method of constructing the vector diagram of a power line, from which it will be possible to read directly the voltage, current, power and power factor at either end of the line.

Theory

The solutions of the equations of voltage and current along a transmission line appear in several forms, of which probably the most useful in power line calculations are the well-known hyberbolic ones

$$E\,g = E\,r\cosh\,(n\,\theta) + I\,r\,Z\,o\sinh\,(n\,\theta) \qquad (1)$$

$$I\,g = I\,r\cosh\,(n\,\theta) + \frac{E\,r\sinh\,(n\,\theta)}{Z\,o} \qquad (2)$$

where

$E\,g$ = generator voltage $E\,r$ = receiver voltage
$I\,g$ = generator current $I\,r$ = receiver current
$n\,\theta$ is the hyperbolic angle of the line, depending on the length n, the size and configuration of the conductors, and the frequency.
$Z\,o$ is the surge impedance of the line, depending on the size and configuration of the conductors and the frequency.

The use of these equations and the technique of hyperbolic functions have been discussed by a number of authors to which a few references are given in the bibliography, so I will not burden this paper with a further discussion. The usual method of solving these equations is an analytical one. This works well enough when the power factor of the load is known, but when condensers are used for voltage regulation, the solution is very complicated. A graphical solution, however, offers several advantages which cannot be overlooked.

Construction of Vector Diagram

The voltage equation. Fig. 1, shows the voltage diagram. In both the voltage and current diagrams $E\,r$ will be used as the reference vector from which all angles will be measured. From O draw $E\,r$ the refer-

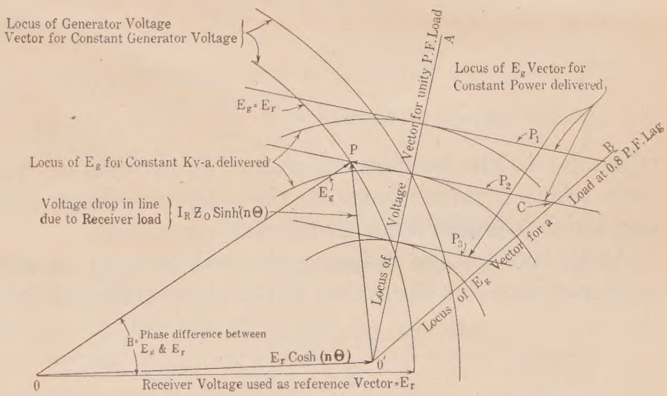

FIG. 1—VECTOR DIAGRAM OF HYPERBOLIC EQUATION $Er\cosh(n\theta) + Ir\,Zo\sinh(n\theta)$.

ence vector. $E\,r\cosh\,(n\,\theta)$ will be shorter and lead $E\,r$ by a small angle. $E\,r\cosh\,(n\,\theta)$ is the generator voltage when the line is on open circuit. The difference between it and $E\,r$ is the voltage rise or Ferranti effect in the line.

Now as we put a load on the end of the line, there will be an impedance drop or rise in the voltage between the receiver and generator ends, depending upon the power

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factor of the load. This is no different from the usual impedance drop in a circuit and is proportional to the current delivered at the receiving end. It is described by the term $I\,r\,Z\,o \sinh(n\,\theta)$ and is represented by the vector $\overline{O'\,P}$.

The position of the vector $\overline{O'\,P}$ depends on the character of the load. With a unity power factor load at the receiving end the point P will move along $O'\,A$. If the amount of power delivered is kept constant while the power factor is varied, P will move along a line perpendicular to $O'\,A$. With a constant kv-a. load, P will move along the arc of a circle drawn from O' as a center. In order to keep the generator voltage constant as the load on the line is varied, the point P must follow the arc of a circle drawn from O as a center and having a radius equal to $E\,g$.

Current Equation. This current equation:

$$I\,g = I\,r \cosh(n\,\theta) + \frac{E\,r \sinh(n\,\theta)}{Z\,o}$$

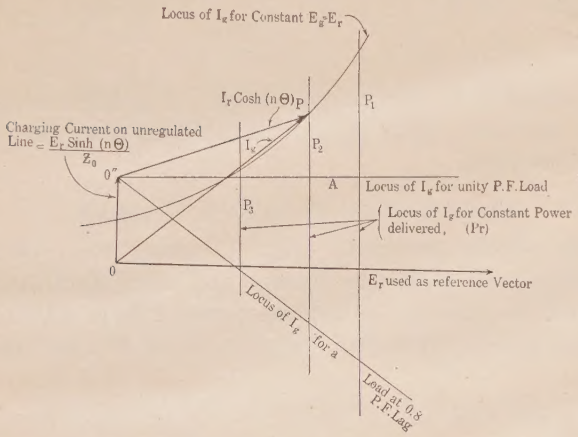

FIG 2—VECTOR DIAGRAM OF HYPERBOLIC EQUATION

$$Ig = Ir \cosh(n\theta) + \frac{Er \sinh(n\theta)}{Zo}$$

is similar to the voltage equation. It consists of one term which is proportional to the receiver voltage and one which is proportional to the receiver current.

As in the voltage diagram $E\,r$ will be used as the reference vector. From O in Fig. 2, draw $\overline{O\,O''}$ equal to

$$\frac{E\,r \sinh(n\,\theta)}{Z\,o}.$$

This is the charging current taken from the generator when the voltage at the receiving end of the line is $E\,r$. It is necessary to state it in terms of the receiver voltage since all calculations are performed on the assumption of a predetermined receiver voltage. As we load the line at the receiver end by taking a current $I\,r$, a current $I\,r \cosh(n\,\theta)$ will be added to the charging current. This component is almost in phase with the receiver current and a little smaller in magnitude. It is represented by the vector $\overline{O''\,P}$.

With a unity power factor load, P will be on the line $O''\,A$. With constant power and varying power factor, P will travel along a line perpendicular to $O''\,A$. Similarly the locus of P for constant kv-a. load will be a circle drawn from O'' as a center.

Let us examine the voltage and current diagrams together. Any point P on either diagram represents a certain amount of power at a certain power factor which is taken from the line at the receiving end. The vector on the voltage diagram is equal to the generator voltage necessary to maintain a receiver voltage $E\,r$ while P is being delivered. The vector $\overline{O\,P}$ on the current diagram represents the generator current while P is being delivered. For every point on the voltage diagram, there is a corresponding point on the current diagram.

Let us assume the system to which the line is connected takes a load from the line at 0.80 power factor. Then the locus of point P of the voltage vector $E\,g$ will be the line $O'\,B$ where $A\,O'\,B$ is the angle whose cosine equals 0.80; and there will be considerable voltage drop between the generator and receiver for a large amount of power transmitted.

In order to avoid raising the generator voltage to maintain constant receiver voltage, synchronous condensers are used. Their purpose is to draw sufficient reactive current through the line to change the power factor from that of the system load to that necessary for the point P to fall on the constant generator voltage curve. In Fig. 1, the drop caused by this current is the vector $\overline{C\,P}$. Changing the condenser excitation causes $E\,g$ to move along the constant power line P_2.

CALCULATIONS FOR A THREE-PHASE LINE.

The following calculation for a three-phase line is given to illustrate the technique and procedure.

Conductor	Aluminum Steel 605,000 cir. mil aluminum. 78,500 steel Diameter = 0.953 inch		
Spacing	Horizontal three conductors 204 inches between conductors.		
Line Constants	n = length of line	=	241 miles
	f = frequency	=	50 cycles
	$w = 2\,\pi\,f$	=	3.14159 radians per sec.
	r = resistance	=	0.1511 ohm per mile
	L = inductance	=	0.0021015 henry per mile
	c = capacity	=	0.01425×10^{-6} farad per mile
	g = leakance, so small we will neglect it.		

From these constants we will determine the hyperbolic angle θ and the surge impedance $Z\,o$. The mathematics of hyperbolic functions in line calculations has been treated so often before that I will do no more than give the formula. Reference to the theory is given in the bibliography.

$$\theta = \sqrt{(r + j\,L\,w) \times (g + j\,c\,w)} \text{ hyperbolic radians per mile}$$

$$Z\,o = \sqrt{\frac{r + j\,L\,w}{g + j\,c\,w}} \quad \text{ohms surge impedance}$$

$$L\,\omega = 0.0021015 \times 50 \times 2\,\pi$$
$$= 0.660205 \text{ ohm per mile}$$

$$(r + j\,L\,w) = (0.1511 + j\,0.660205)$$
$$= 0.6773\ \underline{/77.^\circ 09} \text{ ohms per mile}$$

$$c\,w = 0.01425 \times 10^{-6} \times 50 \times 2\,\pi$$
$$= 4.4767 \times 10^{-6} \text{ mho per mile}$$

$$(g + j\,c\,w) = (O + j\,4.4767 \times 10^{-6})$$
$$= 4.4767 \times 10^{-6}\ \underline{/90.^\circ} \text{ mho per mile}$$

available, the complex functions can be easily calculated from tables of real circular and hyperbolic functions which are found in every handbook.

$$\text{Cosh } (n\,\theta) = 0.915\ \underline{/1.^\circ 20}$$
$$\sinh\ (n\,\theta) = 0.410\ \underline{/83.^\circ 9}$$

$$Z\,o \sinh\,(n\,\theta) = 389.0\ \overline{\backslash 6.^\circ 45} \times 0.410\ \underline{/83.^\circ 9}$$
$$= 159.5\ \underline{/77.45} \text{ ohms.}$$

It is decided to maintain a voltage between wires of 220,000 volts at the receiving end. This gives the voltage to neutral $E\,r = 127{,}200\ \underline{/0^\circ}$ volts

$$E_r \cosh\,(n\,\theta) = 116{,}400\ \underline{/1.^\circ 20} \text{ volts}$$

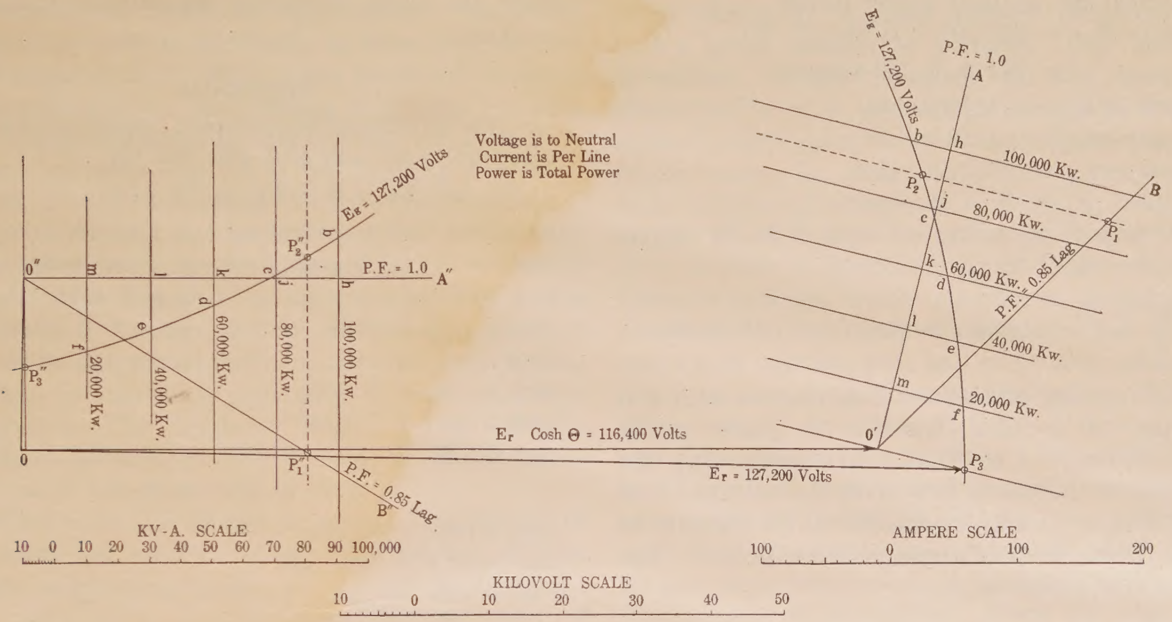

Fig. 3

$$\theta = \sqrt{0.6773\ \underline{/77.^\circ 09} \times 4.4767 \times 10^{-6}\ \underline{/90.^\circ}}$$
$$= \sqrt{3.0321 \times 10^{-6}\ \underline{/167.^\circ 09}}$$
$$= 1.7412 \times 10^{-3}\ \underline{/83.^\circ 54} \text{ hyperbolic radians per mile}$$

$$Z\,o = \sqrt{\frac{0.6773\ \underline{/77.^\circ 09}}{4.4767 \times 10^{-6}\ \underline{/90^\circ}}}$$
$$= \sqrt{0.15125 \times 10^{6}\ \overline{\backslash 12.^\circ 91}}$$
$$= 389.0\ \overline{\backslash 6.^\circ 45} \text{ ohms surge impedance.}$$

$$n\,\theta = 241 \times 1.7412 \times 10^{-3}\ \underline{/83.^\circ 54} \text{ hyperbolic radians}$$
$$= 0.420\ \underline{/83.^\circ 54} \text{ hyperbolic radians.}$$

Since $(n\,\theta)$ is a complex hyperbolic angle, tables or charts of complex hyperbolic functions are of great advantage in determining sinh $(n\,\theta)$ and cosh $(n\,\theta.)$ Such charts and tables have been calculated and published by Doctor Kennelly.[1] If no such tables are

1. A. E. Kennelly, Tables of Complex hyperbolic and circular functions, Harvard University Press.

A. E. Kennelly, Chart Atlas of complex hyperbolic and circular functions, Harvard University Press.

$$\frac{E\,r \sinh\,(n\,\theta)}{Z\,o} = \frac{127{,}200\ \underline{/0^\circ} \times 0.410\ \underline{/83.^\circ 9}}{389.0\ \overline{\backslash 6.^\circ 45}}$$
$$= 134.1\ \underline{/90.^\circ 35} \text{ amperes}$$

Choose a suitable voltage scale, say 10,000 volts to the inch, and from O (Fig. 3) lay off $E\,r$, the reference vector. Draw $\overline{O\,O'}$ equal to $E\,r \cosh\,(n\,\theta)$ leading $E\,r$ by an angle of 1.20 degrees. For 100,000 kw. delivered at the receiving end at unity power factor, $I\,r$ will equal 263. $\underline{/0^\circ}$ amperes per phase.

$$I\,r\,Z\,o \sinh\,(n\,\theta) = 263\ \underline{/0^\circ} \times 159.5\ \underline{/77.^\circ 45}$$
$$= 41{,}900\ \underline{/77.^\circ 45} \text{ volts}$$
$$= 4.19\ \underline{/77.45} \text{ inches}$$

From O' draw $O'\,A$ making an angle of 77.45 deg. with $E\,r$. This is the unity power factor line. Measure up 4.19 inches from O' and through the point draw a line perpendicular to $O'\,A$. This is the 100,000-kw. line. Distances along $O'\,A$ are proportional to the power delivered at the receiver at unity power factor. We can therefore get a power calibration.

4.19 inches = 100,000 kv-a.
or 23,820 kv-a. = 1 inch

From O draw an arc the radius of which is equal to the generator voltage it is decided to maintain by means of condensers. This arc will intersect the constant power lines at b, c, d, e, f.

Current Diagram. For convenience in reading, we will construct the current diagram on the same sheet and to the same scale as the voltage diagram. Since $I\,r\,Z\,o \sinh(n\,\theta)$ and $I\,r \cosh(n\,\theta)$ are both proportional to $I\,r$, if we use the proper scales we can transfer power points from one diagram to the other with a pair of dividers. Such a current scale is one which will make $I\,r\,Z\,o \sinh(n\,\theta) = I\,r \cosh(n\,\theta.)$

For 100,000 kw. at unity power factor

$$I\,r \cosh(n\,\theta) = 263\ \underline{/0°} \times 0.915\ \underline{/1.°20}$$
$$= 241.8\ \underline{/1.°20} \text{ amperes}$$

$I\,r\,Z\,o \sinh(n\,\theta)$ = 4.19 inches
241.8 amperes = 4.19 inches
1 ampere = 0.01741 inch
1 inch = 57.7 amperes

From O draw $\overline{O\,O''}$ making an angle of 90.35 degrees with $E\,r$ and equal to

$$\frac{E\,r \sinh(n\,\theta)}{Z\,o} = 134.1 \text{ amperes} = 2.322 \text{ inches.}$$

Draw $O''\,A''$ making an angle of 1.20 degrees with $E\,r$. With a pair of dividers, transfer the power points h, j, k, l, m, from $O'\,A$ to $O''\,A''$. In a similar way, the intersections of the power lines with the voltage curve (points b, c, d, e, f,) may be transferred to the current diagram. Draw a circle through these points. The diagram is now complete.

Use of the Diagram

It is desired to know the terminal conditions when 90,000 kw. is being delivered at the receiving end at 0.85 power factor. Draw $O'\,B$ the 0.85 power factor line. This is drawn at such an angle that $A\,O'\,B = \cos^{-1} 0.85$. Measure up 90,000 kw. along $O'\,A$ and draw the constant power line through the point. The intersection of the constant power line and the constant power factor line determines the power point P_1. The generator voltage required to deliver this power is the vector $\overline{O\,P_1}$ and is equal to 150,600 volts and leads $E\,r$ by 13.5 degrees. To bring the generator voltage down to 127,200 volts will require an amount of condenser capacity equal to $P_1 \,.\, P_2$ or 62,800 kv-a. The generator voltage vector will be $O\,P_2$ and will lead $E\,r$ by 18.6 degrees.

Locate P_1'' and P_2'' on the current diagram to correspond to P_1 and P_2 on the voltage diagram. Then $O\,P_1''$ is the generator current when no condensers are used, and is equal to 220.0 amperes. The generator power factor is the cosine of the angle $P_1\,O\,P_1''$. $P_1\,O\,P_1'' = 12.°3 \cos 12.°3 = 0.977$.

The total three-phase power delivered by the generator is $3 \times 150{,}600 \times 220.0 \times 0.977 = 97{,}100$ kw. The line loss is equal to $97{,}100 - 90{,}000 = 7100$ kw.

The vector $\overline{O\,P_2''}$ is the current when the generator voltage is regulated to 127,200 volts. It is equal to 275 amperes. The power factor is the cosine of the angle $P_2''\,O\,P_2$. Power factor = 0.945.

$P_g = 3 \times 127{,}200 \times 275 \times 0.945 = 99{,}000$ kw.

Line loss $= 99{,}000 - 90{,}000 = 9000$ kw.

To keep the generator voltage constant at no load will require a lagging condenser capacity equal to $O'\,P_3$ or 28,900 kv-a. This is very small when compared with the full load condenser capacity. It would, therefore, be more economical from the point of view of buying condensers to choose a voltage which would require the same condenser capacity at full load as at no-load.

Appendix

Method of calculating complex hyperbolic functions. To find sinh and cosh of $0.420\ \underline{/83.°54}$

$$0.420\ \underline{/83.°54} = 0.04755 + j\,0.4170$$
$$\sinh(u \pm j\,v) = \sinh u \cos v \pm j \cosh u \sin v$$
$$\cosh(u \pm j\,v) = \cosh u \cos v \pm j \sinh u \sin v$$

$u = 0.04755$ $\quad v = 0.4170$
$\sinh u = 0.047567$ $\quad \sin v = 0.4049$
$\cosh u = 1.001132$ $\quad \cos v = 0.9143$
$\sinh u \cos v = 0.0435$
$\cosh u \sin v = 0.0450$

$$\sinh 0.420\ \underline{/83.54} = 0.0435 + j\,0.4050$$
$$= 0.409\ \underline{/83.°9}$$

$\cosh u \cos v = 0.915$
$\sinh u \sin v = 0.01923$

$$\cosh 0.420\ \underline{/83.54} = 0.915 + j\,0.01923$$
$$= 0.915\ \underline{/1.°2}$$

This method of calculation gives a little more accurate result than it is possible to get with the charts or tables.

If, instead of using the hyperbolic functions, it is found more convenient to use the Steinmetz equations:

$$E\,g = E\,r\,(a_1 - j\,a_2) + I\,r\,(b_1 - j\,b_2)$$
$$I\,g = E\,r\,(d_1 - j\,d_2) + I\,r\,(a_1 - j\,a_2)$$

the procedure will be just the same, except that in these equations the phase rotations are reversed.

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Developments in Telephotography

BY D. W. ISAKSON
Associate, A. I. E. E.
Utah Power & Light Company, Ogden, Utah.

Transmitting photographs, drawings, maps, etc., by wire or wireless is a problem to which a solution is near at hand, and the present paper is given anticipating the addition of this to our already long list of applied sciences. A brief history is given of the early beginnings, and some of the modern methods discussed; among the latter being Korn's and Belin's. The Leishman systems are discussed at length because the author has been particularly interested in their development and has been in intimate contact with both inventor and inventions.

In the present paper it is hoped that interest of the American engineer may be stimulated in this subject to the end that a successful solution might rightfully be attributed to American genius.

THE art of transmitting an optical image to a distance by means of an electric circuit, though we may trace its early beginnings back some seventy years or more, has hardly yet derived results which warrant its commercial application. The entire field today is confined practically to some three or four distinct systems all of which have produced excellent experimental results. And though it has not yet come to any widespread practical application, we may safely anticipate an early solution of the existing problems. Since this art may soon take its place with telephony, telegraphy, etc. as an applied science, the author believes that the present paper will be of interest to those who have followed, or have contributed to the development of this art, and in the following text will endeavor to describe briefly its history and outline briefly the fundamental principles of each important development. The Leishman Code System will be dwelt upon at greater length because of the more general use it has come into in America.

As stated in the preceding paragraph, *i. e.* the art of transmitting an optical image, the subject divides itself into two general heads; the first, of which may be termed television. This indicates the operation of reproducing upon the apparatus of the receiving station an animate object or image coming within the focus of the transmitting apparatus. Under the second head, which may be generally termed telephotography, and which consists in the reproduction upon receiving apparatus, of an ordinary or especially prepared photograph sent out as electrical impulses or suitable signals from the transmitting station. Though several, including Rignoux, Fournier, and A. Campbell Swinton, have suggested possible solutions the former remains as yet entirely chimerical, and in this paper discussion will be confined solely to the development of the telegraphic transmission of photographs.

The field for application of a system for telegraphing pictures economically is fairly obvious. Its use in warfare, in the speedy transmission of photos, maps, etc. should insure its early adoption by governments; the dispatch with which photographs and finger prints of wanted criminals could be transmitted to all the haunts of civilization would make it an invaluable instrument in the hands of the police in the discouragement of crime; and the growing demand for illustrated news argues well for its commercial development from the investors point of view. We find it, then, from every viewpoint, a much desired invention and one with a great mission to perform. Yet unlike other inventions equally needed, it has been nearly three-fourths of a century in coming to a practical state of development. Very naturally we may wonder at the reason for such slow progress, but very likely after a thorough study of the situation we should be unable to attribute a tardy success to any single one of a number of possible reasons. For we find it an intricate problem, involving complex combinations of the physics of light and of electricity and of the mechanics of motion, etc., and of peculiar properties of elements, compounds and substances which have differed widely from time to time as various investigators have attacked the problem. The chief difficulties that have been encountered by such investigators may be brought out in the following brief description of their individual processes and apparata, and thereafter we may draw conclusions as to their bearing upon the development of the science. From this, also, we may derive an adequate idea of the intrinsic value of the work of early experimenters, as their principles may affect or facilitate the work of subsequent investigators.

In ordinary telegraphy we find it quite impossible to transmit simultaneously the entire contents of a printed page. But by a simple process of splitting it up, first into lines then each line into the words that compose it and further, each word into its constituent letters, we may, by means of suitable signals, and by transmitting one letter at a time, reproduce the entire contents of the printed page to a distant station. The process in telegraphing a photographic image is fundamentally the same. Only one minute portion of the composite photograph can be transmitted at a given instant. These minute portions are arranged mechanically into lines and are read by suitable mechanical means. The apparatus therefore must necessarily consist of, first, a means for dividing the photograph into extremely small component parts; second, a means for interpreting the varying degrees of shading of each component part into varying intensities of electric current; third, a means whereby the variation in the electric

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current can again be interpreted at the receiving station into light and shade variation corresponding both in intensity and in relative position with that of the original photograph. In practise, the third fundamental involves a fourth, that of maintaining exact synchronism in the mechanical motion of the sending and receiving apparatus. Having in mind these fundamental requirements which are common to all methods, we may proceed in a description of the varying ways in which they have been carried out.

As early as 1847 Bakewell constructed an apparatus whereby he was enabled to transmit telegraphically, drawings, handwriting and pen sketches over a distance of several miles. Though this cannot strictly be considered a system for sending photographs—photography at that date not being in a sufficient state of development to lend of its application in such a new and untried field—we may consider it the beginning, since upon the principles of this scheme have subsequent experimenters worked. It consisted essentially of two

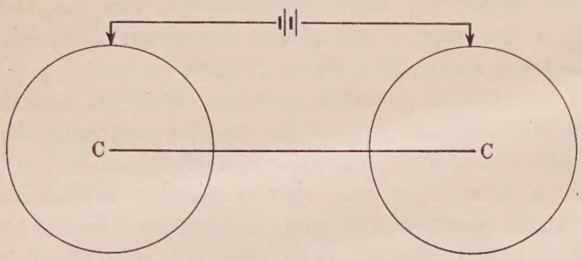


FIG. 1

metal cylinders (one at the sending and one at the receiving station) which revolved synchronously under a stylus contacting upon the surface of each. The stylus was mounted upon a threaded shaft geared to the shaft of the cylinder. In operation the stylus was thus caused to move laterally as the cylinder revolved and to trace a spiral path upon its surface. The subject sketch drawn in insulating ink upon a sheet of tinfoil was mounted upon the first cylinder. A sheet of chemically prepared paper was mounted on the second. The circuit was completed as in Fig. 1. With the current interrupted by the passage of a line of the insulating ink under the stylus, the electrolytic action of the current upon the paper at the receiving station receives a corresponding interruption. With the cylinders in perfect synchronism and the stylus having traversed the entire length of its screw shaft, the lines constituting the original drawing are reproduced upon the chemically prepared paper at the receiving end. To maintain synchronism a series of impulses was transmitted at regular intervals which electromagnetically actuated the clockwork which furnished the motive power for the apparatus. The difficulties in maintaining synchronism, distortion caused by the capacity and inductance of long cables, and other difficulties encountered caused an early abandonment of the scheme.

For many years thereafter no noteworthy results were obtained although several schemes were suggested. In 1859, an Italian priest, Abbe Casseli, had a model of his famous pan telegraph built. Casseli's apparatus, which was both original and ingenious, consisted of a swinging pendulum to which was fastened an arm carrying the stylus. The stylus was caused to trace a line over the surface of a plate which was shifted laterally the width of one line with each oscillation of the pendulum. The receiving pendulum was electrically actuated by a series of impulses caused by the closing of contacts by the transmitting pendulum with each oscillation. With this arrangement absolute synchronism was very easily maintained. The subject sketch was drawn with shellac ink upon the copper plate of the transmitting machine, and a paper prepared in a solution of ferricyanide was placed upon the plate of the receiving machine. Thereafter the actual reproduction was very similar to that of Bakewell, previously described. With this method, excellent results in transmitting handwriting, drawings, etc. were obtained at a comparatively high rate of speed. Perfect synchronism was easily maintained, but we find the field for such an instrument very limited as compared with the cost of construction and operation of stations, and consequently it, too, failed to be utilized commercially.

DeMeyer (1869), D'Arlincourt, Gras and other Frenchmen experimented on similar lines, but with no noteworthy results. In a process suggested by Amstutz we find probably the first concerted attempt to telegraph a photograph. In his process the photographic negative is printed upon a gelatinous prepared paper rendered light sensitive by the addition of bichromate of soda. The emulsion properly prepared has the property of becoming soluble in warm water after exposure to actinic light. The paper prepared with a thick coating of the emulsion is printed in the regular manner and further developed in warm water. The positive thus prepared will have an irregular surface representing the high lights by depressions or hollows and the shadows by hills or prominences. This positive replaced the tinfoil of Bakewell's process upon the transmitting cylinder. A stylus actuated a sort of microphone over its surface with the result that the current in the telegraphic circuit, instead of being periodically interrupted, was caused to vary in its strength, representing a light portion by a weak current and a dark portion by a strong current, since the diaphragm, while the stylus is passing over a prominence, is caused to compress the carbon grains, thus decreasing their resistance. The current in the line will then be theoretically proportionate to the shading of the original photograph at the point touched at any instant by the stylus. To translate such current variations into the black and white of a photograph, Amstutz proposed to use the received current in the direct engravure of a single-line half-tone. To accomplish this, the received current was to regulate,

by means of electromagnets, the cutting depth of a V-shaped stylus upon a copper plate wound around the receiving cylinder.

Quite obviously such a receiving apparatus is out of the question, since a current strong enough to perform so much work would necessitate a voltage for its transmission quite beyond the capacity of any transmitting device that could possibly be constructed. Thus, through lack of a receiving device, Amstutz failed. His transmitting device was later, however, to figure in the more or less successful scheme of Belin, which will be described in its due order.

In 1873, while conducting some experiments in which selenium was used as a resistance, Willoughby Smith was annoyed by the peculiar instability of his resistance and upon investigation found that selenium possessed the peculiar property of varying its electrical conductivity with the intensity of the light to which it was exposed. With the announcement of this discovery, several attempts were made to utilize these properties in various ways. Notable among these may be mentioned the cell constructed by Prof. Bell which played the principal role in the operation of his famous photophone. It was Shelford Bidwell who first suggested its use in the problem of phototelegraphy. He conducted

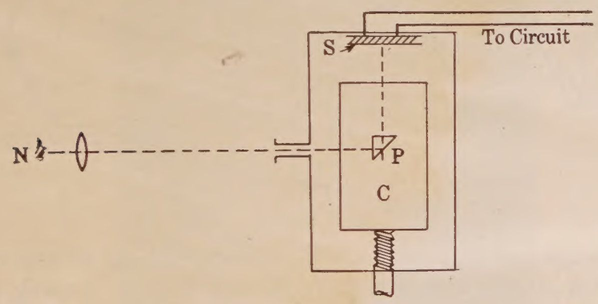


Fig. 2

some very interesting experiments in thus applying it, as did also Perry and Ayrton.

It remained, however, for Prof. Korn[1] of Munich actually to transmit and receive the first photograph by this means (probably the first to telegraph photographs by any means). His fundamental apparatus is depicted in Fig. 2, where C is a glass cylinder rotating upon a threaded shaft within a dark box and upon which is mounted the subject photograph printed on a transparent celluloid film. The prism P is so placed within the cylinder as to reflect the Nernst beam, which is focused through an aperture in the dark box, upon the selenium cell S, situated at one end of the box. Thus, having passed through the film, the light received by the selenium cell will obviously be a function of density variations in the photographic film as the cylinder rotates and moves laterally. And since the conductivity of the cell is functional with the light which acts upon it, the current in the telegraphic circuit will be at a given instant, directly proportional to the density of the silver deposit upon the film at the particular point through which the light beam instantaneously passes.

Theoretically, such a process encounters no difficulties. In practise, however, the characteristic recovery lag of selenium must be dealt with. If an abscissa represents the time and an ordinate the current, then the conductivity in a cell suddenly exposed to a light of given intensity for a time $L\,O$, may be represented

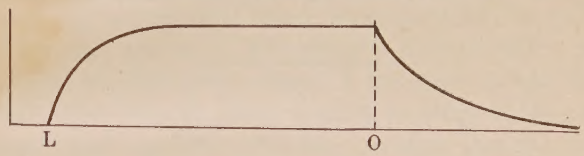


Fig. 3

by the curve in Fig. 3. Grantham[2] found by experiment that the resistance actually increased for an instant on exposure. Characteristic lag may be great enough in some instances to last over a period of several seconds, depending upon the purity of the selenium used, upon the construction of the cell, and in a measure upon the temperature under which the cell may be functioning, since its maximum sensitivity has been found to be at 0 deg. cent. Thus it will be seen that with the cylinder rotating at its lowest possible practi-

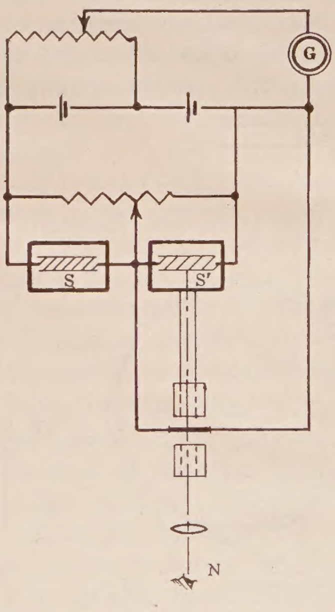


Fig. 4

able speed, the detail of the original photograph will be lost to such an extent as to give an unrecognizable reproduction at the receiving station. Korn overcame this objectionable feature to a great extent by means of his compensation method. This comprises a bridge arrangement with a selenium cell in each arm. S is in a separate dark box and is acted upon by the light from the photograph. S' is in a separate dark box and is

1. T. T. Bakers "Telegraphic Transmission of Photographs."

2. Grantham, *Physical Review.*

acted upon by the light from a Nernst lamp. The Nernst beam is intercepted by a shutter electrically operated by the galvanometer G of a modified Einthoven type. With the passage of current in the circuit, the silver wire bearing the shutter is displaced, permitting a portion of the Nernst beam to fall upon S. With this arrangement Korn claims to have improved the sensitivity of the selenium circuit and to have obtained an effect represented by the curve in Fig. 5. At the receiving end, the Nernst beam was

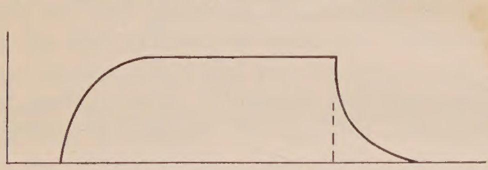


Fig. 5

focused upon a sensitized paper. Here again the beam was intercepted by the electrically operated shutter. The displacement of the silver wire bearing the shutter in the galvanometer field is theoretically proportional to the current which flows through it. Thus the light which falls upon the sentitized paper on the receiving cylinder will be proportional to the current in the circuit. To maintain synchronism, an impulse each revolution caused both machines to stop and reset to a predetermined starting point. With this apparatus Korn created considerable interest and its application in the journalistic field was attempted in several of the larger cities of Europe. In the extreme delicacy of the

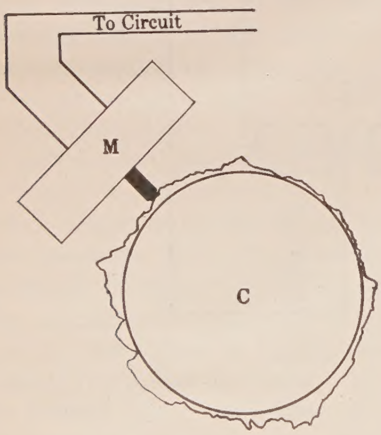


Fig. 6A

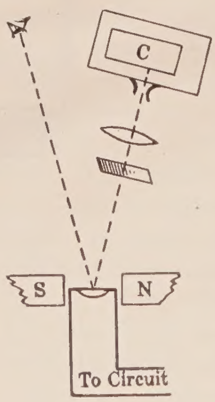


Fig. 6B

mechanism is found probably its greatest fault. Then, too, with difficulties encountered in maintaining synchronism, and the comparatively low sensitivity of the selenium cells, Korns selenium system was doomed to go the way of its predecessors.

Korn also realized its limitations, for he soon turned his genius to a system free from the inherent drawbacks of selenium. His next labors brought forth his telautograph. This consisted essentially of a combination of a metal drum and the use of his galvanometer receiving machine.

Of late M. Edouard Belin has come into the limelight of the telephotographic field and has created considerable interest in his telesteriograph, which he very recently brought to America to demonstrate. So much has been written in the daily press, in the technical and semitechnical periodicals of the country of M. Belin's apparatus, that its description must still be fresh in the minds of those to whose attention the present paper may come. It will be necessary here, then, only briefly to review the elemental principles involved in his apparatus.

As has been indicated above, Belin's process for transmitting utilizes the "relief" photograph as developed by Amstutz, and the sending apparatus is essentially the same as that above described. The scheme is depicted in Fig. 6A. At the receiving end, a Duddell type oscillograph is caused to reflect a beam of actinic light (the angle of incidence being proportional to the current in the galvanometric circuit) over a graduated screen containing, to all practical purposes, all the light variations from transparency to opacity (Fig. 6B). The light, thus varied in its intensity from

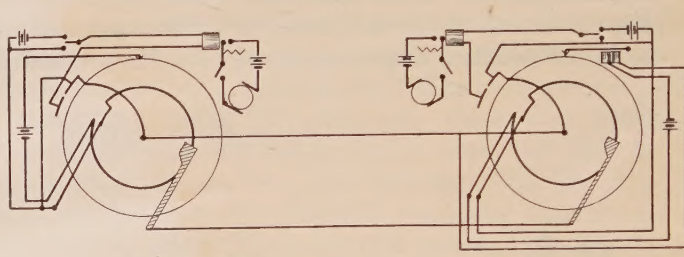


Fig. 7

passage through the screen, is focussed by means of a suitable lens through a small aperture in a dark box in which the cylinder carrying a sensitized paper or films revolves and moves latterly upon a threaded shaft. With the passage of a prominence under the stylus at the transmitting cylinder, the mirror of the oscillograph will be caused to reflect the light beam to the transparent end of the screen, and to the dark end with the passage of a depression under the transmitting stylus. Under development, the sensitized paper or film will represent a faithful reproduction of the original, providing of course that absolute synchronism be maintained between the sending and receiving machines. Some excellent results have been obtained with these instruments and we may hope much from M. Belin's scheme. The French government has been experimenting recently and it is generally understood that some unannounced developments have been made. In warfare, in the criminalistic field and similar applications, its utility seems practicable in the present state of development. In the journalistic field, however, the expenses which its operation entails in the sending of a single photograph make its practical application necessarily very limited.

Possibly the only systems for telegraphing pictures

that have been developed in America and that have attained any notable success in the commercial field are those of L. J. Leishman. The first of his two systems was brought into experimental use by the government during the recent war.

His first system, called "screen process" because the preparation of the subject photograph is similar to the process used in preparing newspaper half tones, is meritorious in that it has done much to eliminate complex and complicated apparatus of previous methods. In this method the subject photograph is printed through fine mesh screen, (the purpose of which is to separate the picture into its minute component parts) upon a copper plate coated with a solution of glue and bichromate of ammonia. The positive is developed in warm water and the glue solution is washed away in proportion to the light having acted upon it. The developed positive presents a

Fig. 8—Photograph of the Mayor of Los Angeles as Received by Telegraph

surface of dots of varying sizes, areas of small or no dots representing the high lights and vice versa. For half tone work the plate of course much be etched which changes the plate again into a negative for printing purposes. With the glue only on the plate however, it represents a positive and it is in this state that it is used for picture telegraphy. The plate is formed into a cylinder and slipped on to the cylinder of the sending machine where a stylus traveling upon its surface and closing the telegraphic circuit, sends out electric impulses varying in length as to the distance between dots. Here we are brought face to face with a reincarnation of Bakewell's metal cylinder having on its surface drawings and writings done in insulating ink and rotating under the contacting stylus, and we may be struck with thought that it isnt such a very far cry from those early attempts of 1847 to the present-day attempts to solve the same problem. The similarity in the two methods ceases, however, with the sending cylinder and the contacting stylus. At the receiving station the impulses as sent by the sending machine are interpreted into the various tones of the original photograph by a means as simple as it is ingenious. The current in the telegraphic circuit passes through two electromagnets actuating an armature bearing a sapphire stylus at its end. Fig. 7. As the impulses from the sending apparatus pass through the electromagnets the stylus is brought to bear upon the receiving cylinder which has around it an ordinary piece of white paper over which has been placed a sheet of carbon paper. With each impulse then, a mark is made on the white paper and as the cylinder revolves synchronously with the sending cylinder the photograph is gradually built up. Fig. 8 represents a photograph received by this method.

In this system a novel and superior method of synchronizing is used. Korn, Belin and others have synchronized by momentarily stopping one or both of the revolving cylinders. In the newly developed method both cylinders are permitted to revolve continuously. This is accomplished by means of the relays controlling the motor circuit. Batteries actuating the relays are so connected that their current flow is neutralized when the machines are in synchronism. If one machine leads, current flows through the relay controlling its motor circuit and the motor is slowed down in proportion to the lead attained by the machine. It will readily be seen that this is a factor toward faster transmission, and very nearly absolute synchronism is maintained.

Interruptions to the circuit take place at an average speed of 250 times per second; a fact that renders its use on ordinary telegraph lines impossible, since the relays in general use are of a low-speed type. This objection may of course be overcome by vacuum tube relays. Mr. Leishman, however, unsatisfied with this, has turned his genius to what promises to be a long step forward for this science.

In the new process, Leishman utilizes the photoelectric cell in place of selenium, as used by Korn, in surmounting the inherent difficulties that limit its application. Selenium cells have been used during the last ten years in astronomical measurement of light from stars and planets, but it has been discarded in this work owing to the time necessary for recuperation after exposure and to its susceptibility to climatic influences. Highly satisfactory, in fact we might say perfect, results have been obtained in this work in recent years by the use of the gas photo-electric cell as developed by Kunz. This cell recuperates instantaneously, is not susceptible to climatic conditions and has the light sensitiveness of the human eye. With this system, a film on a rotating glass cylinder is used.

For receiving a picture transmitted by this process, Leishman has used a means that will entirely eliminate

Fig. 8a—From an Actual Photograph which is to be Sent over the Wires

Fig. 8b—Photograph with Features Outlined and Shadows Divided into Five Degrees of Shade

gravity, friction and mechanical inertia, factors which tend materially to limit the speed of transmission.

LVGIS	MBGWQ	MJIJQ	MTITQ
QJJBQ	QUJDQ	SDIXQ	SQISQ
TEIBQ	TGGQQ	TMFQQ	TSEUA
TDEKA	SMEUQ	QXEMQ	QJEQQ
MVEQQ	MJEKA	MEEIQ	MDETQ
MBFWQ	LVGIQ	LMGKQ	LIGMQ
KVFWQ	KTFTQ	LDFBQ	LAEWQ
LJEGQ	LQDQQ	LUBWQ	MQAVQ
SAAMQ	SKAMQ	TDAVQ	TLBIQ
TUBTQ	TXBVQ	TVDAA	TXDDQ
UADMQ	UAEIQ	TWELA	UBETQ
TXFPQ	TUFQQ	TVFVQ	TUGAQ
TWGMQ	UAGXQ	TSIGQ	TGIFQ
MQFEE	QFFEQ	QMFIQ	QSFMG
QSFAQ	QBEWA	QAEVA	MMEVQ
QAFDM	QJFDM	MTFFE	QBFFQ
QMFLG	QGFLQ	MXFJQ	MTFFD
QAFIQ	QEFKQ	QGFJQ	QIFGK
QBFIQ	QFFJQ	QFFIQ	QEFFM
QFFGV	QJFIS	QKFKA	QFFLK

Fig. 8c—This is Part of the Photogram or Code Telegraphic Message—the Form in which the Picture is Flashed over the Wires.

Fig. 8d—This is the Complete Outline Obtained from the code, with Proper Shade Letters within Enclosures.

An electromagnet carrying the current of the telegraphic circuit is caused to rotate in the plane of

Fig. 8e—This Shows the Shadows Roughly Blocked Out—Poster Effect

Fig. 8f—And This is from the Finished Picture Ready for Publication. Compare A with F

a polarized beam of light. The degree of rotation is a function of the current in the circuit and the intensity of the light passing the second Nichol prism will depend on the degree of rotation. This method for varying the intensity of the light beam was first suggested by Rignoux and Fournier. This method necessitates the use of the film on the receiving cylinder through which the light beam is carried. This method produces a pure half-tone picture upon the receiving film.

We have seen that picture transmission consists essentially in building up a photograph at the receiving station by placing correctly component parts of the original and by giving each the proper degree of shading. Thus far the systems we have studied have accom-

Fig. 8g

The code system was perfected with the needs of a newspaper in mind. A newspaper uses 60 line screen in making its cuts, and therefore neither the original or reproduction would have the clearness or detail shown in these cuts of 100 line screen. The fine screen was used here to make them look as near like the actual pictures as possible, but on account of the detail shown by the fine screen the original and reproduction—A and F—do not look as much alike as they would if printed in a newspaper.

Not only is this due to the screen itself, but to the fact that detail that will not show clearly in a newspaper cut is *purposely* eliminated, as it is foolish to unnecessarily lengthen a photogram to include details that will not produce in a newspaper picture even if the original itself were used. To show that the code system more nearly meets newspaper needs than the previous cuts would indicate, A and F are herewith reproduced as they would appear in a newspaper—in 60 line screen.

plished this by mechanical means only and only a minute portion is transmitted at any instant. In a code system developed by Lieshman we find a deviation from previous practises and though it involves no new application of pure or applied science we may find it of interest in that it is novel and ingenious and has possibly found a wider commercial use than any other process thus far brought out. In this system a photograph is first split up into component parts; this first step differing from previous methods in that large areas comprising one single shade throughout comprise these parts. In Fig. 8b this first step is illustrated.

Being arranged primarily for rapid distribution of current photographs and illustrations for newspaper work this new system concerns itself with only five gradations of shade, further gradations being un-

necessary from the fact that only that number appear in the ordinary 60-screen newspaper cut. Each shade may be designated by a letter. In practise *X* indicates white; *F* light grey; *I* medium grey; *K* dark grey; and *M* indicates black. For outlining the areas of one solid shade a continuous line is used when its borders are abrupt and distinct, and a dotted line when two degrees of shade blend. After the picture has been divided in this way it is ready for the coding process. The apparatus consists of a drawing board with a scale across the top denoting the abscissa and an ordinary *T* square with a similar scale along its edges marking off the ordinates, (Fig. 9). The scale is divided into 18 prime divisions and each prime division into 18 subdivisions. For designating these divisions, letters are used instead of numbers for two reasons; first, there are nine digits, which with the cypher, make only 10 possible characters that can be used, while the alphabet affords 26. With letters, therefore, any division and subdivision may be designated by only two characters; second, telegraph companies send five letters in code as one work but for numbers each digit is charged for at the word rate. Since in the scale designed only 18 letters are necessary, those most easily confused in telegraphing are omitted.

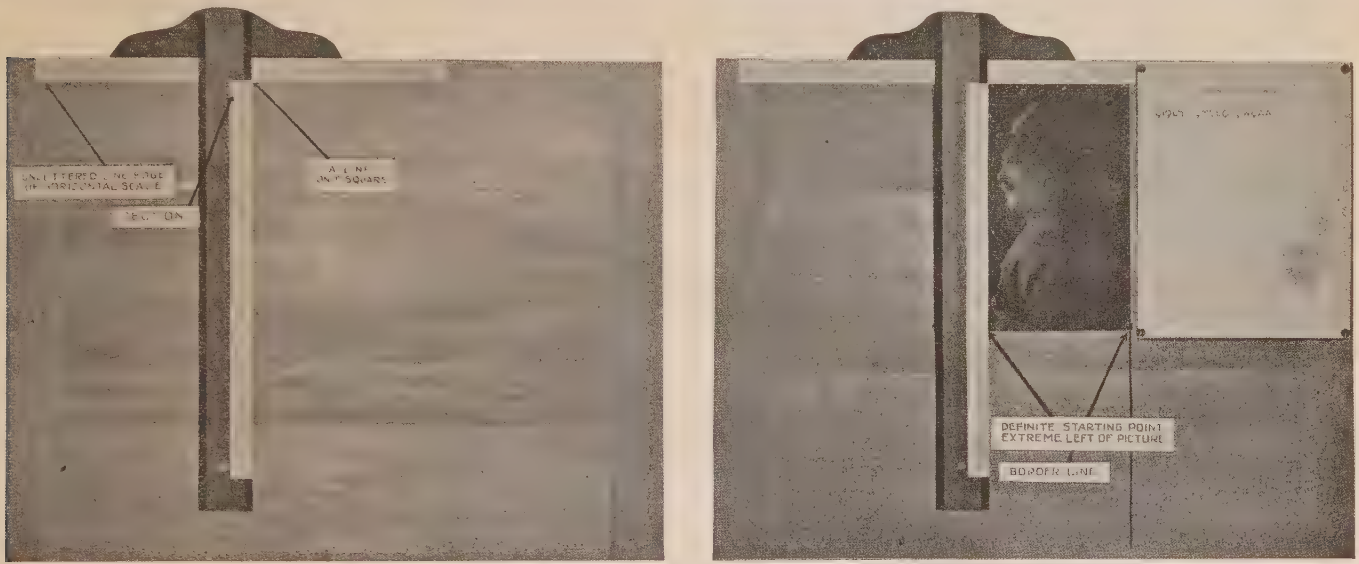


Fig. 9—Coding Board

With the coding board any determined point on a picture, as fixed by a first coding board, may be accurately placed, relative to other points, by a second.

This is very similar to the familiar way of locating towns and cities on maps where longitude may be indicated by figures and the latitude by letters or vice versa. This for instance, were it desired to locate the town of Podunk in a certain map we find in the key opposite the name of Podunk the characters *R*-6. By this we know that the town is in proximity of the point where longitude 6 intersects latitude *R*.

Obviously in picture transmission utmost accuracy is necessary in properly fixing points and it is therefore necessary to use an infinitely great number of ordinates and abscissas. It follows therefore, that more characters are required to express the exact location of points. It is accomplished by using four letters; the first indicates the prime division on the vertical scale and the second the particular ordinate coming within that division. The third tells which of the prime divisions on the horizontal scale contains the abscissas indicated by the fourth letter. As an instance, *L G V I* indicates the co-ordinate of ordinate *G* in prime division *L* on the vertical scale and abscissa *I* in prime division *V* on the horizontal scale.

The lines circumscribing the various shades are divided having in mind the following two geometrical propositions; first, that two points determine a straight line and, second, that three points determine a circle. In coding a straight line the *T*-square is placed with the scale edge of the *T*-square on the first point. Both scales are then read and the *T*-square placed on the second point and scales read.

Telegraph rules permit five letters to a word in code messages and four are used in locating each point along a line. The remaining letter is used to indicate the various processes to the receiving operator; thus:

Letter	*S*	indicates	beginning of a line	
"	*D*	"	end of line	
"	*A*	"	end of straight line	
"	*Q*	"	cusp	
"	*W*	"	end of straight dotted lines	shades to blend
"	*U*	"	cusp dotted	
"	*X*	"	white	
"	*F*	"	light grey	
"	*I*	"	medium grey	
"	*K*	"	dark grey	
"	*M*	"	black	

Letters indicating shading are given when the circumscribing line is completed, *i. e.* brought back to the point of beginning.

A finished picture is shown in the illustration, Fig. 10. This was reproduced from the code by an operator who had never seen the original. With this system hundreds of photographs are being sent through the Leishman

Telegraph Picture Service Company to progressive newspapers in all parts of the country and though its scope is necessarily limited, due to an inability to code and reproduce photographs containing any great amount of detail economically, yet it seems that the field remains sufficiently broad to warrant its development.

Inasmuch as the code system is not electric, except as concerns telegraph instruments, and does not introduce any new principle of physics or mechanics into the field of applied science it may, perhaps, not be of great interest, considered from a purely technical standpoint. Yet, inasmuch as it has been more or less successfully used in replacing more intricate systems the author thinks he is justified in discussing it in the present paper. A photogram, as it has been termed by the inventor, may be relayed any number of times, lends itself to wireless as well as wire telegraphy and is never subject to static and magnetic disturbances nor to the inherent evils of long telegraph and telephone lines; viz., capacitance, inductance, etc.

Fig. 10a— Before Telegraphing: This is from the Original Photograph as it was taken at Sing Sing Prison, N. Y., Just After the Fire

Fig. 10b—After Telegraphing: Picture of the Sing Sing Fire, Published by many Western and Pacific Coast Papers within Twenty-four Hours of the Fire—Really before the Fire was Out

From the preceding description we may rightly conclude picture telegraphy is as yet far from the zenith of its possibilities. A broad field for investigation and experimentation in the application of new and untried laws and phenomena of chemistry, physics, etc.; as promulgated from time to time from the realm of pure science is unfolded to the engineer of tomorrow. Assuredly we may anticipate a great advance in this art during the next decade and we may be hopeful even of a practical solution to the problem of seeing over a wire or by wireless, in fact, some of the foremost European scientists are even now devoting their energies to this end.

SAFETY DEVICES ON ELECTRIC MINE LAMPS

In view of frequent expressions of doubt as to the necessity of the use of a safety device on portable electric miners' lamps designed for use in explosive mine atmospheres which would be effective in opening the bulb circuit whenever the bulb was broken, the Bureau of Mines recently conducted, at the Pittsburgh, Pa., experiment station, a series of tests with bulbs such as are being used today on miner's lamps energized with 2-volt lead cells. The results of the tests afford the most convincing argument as to the necessity of an adequate current-interrupting safety device on miners' electric lamps. In 55 tests in which the naked filament was exposed, either at the beginning or after smashing the bulb, 51 ignitions resulted. These ignitions were all obtained with normal voltage impressed on the bulb filament. Fifteen successive ignitions on one filament showed the toughness of the filament, and how easy it is to get an explosion before the filament is burned through. The 20 smash tests in which 16 ignitions were obtained show that in the majority of cases the filament is in condition to cause ignition after the bulb glass has been broken. Though a time lag in the ignition of gaseous mixture is admitted, these tests show that the time lag of the filament burning through is greater, and consequently can by no means be relied on as a protection against gas ignition. The Bureau of Mines feels that its policy of requiring a safety device on electric miners' lamps is both wise and necessary. The bureau recommends to the user of portable electric lamps more attention to the careful maintenance of the safety devices of such lamps, and discourages the use of any modifications that interfere in any way with their proper operation.

The Bureau of Standards has been conducting experiments in cooperation with the various states on the proper illumination of automobile license plates and their visibility under different conditions of illumination. This work is being continued, but the observations made up to the present time are merely preliminary and include only a few of the conditions under which plates must be legible.

Failure of Disk Insulators on High-Tension Transmission Lines

BY HARRISON D. PANTON
Associate, A. I. E. E.
Yadkin River, Power Company, Rockingham, N. C.

THE writing of this article is prompted by the fact, brought out at several Institute meetings at which papers dealing with disk insulators were discussed, that although much successful research laboratory work has recently been done to determine the electrical and mechanical characteristics of insulators of this type, there is available practically no accurate information showing the actual operating performance of such insulators during a period of years. Having recently compiled certain information of this kind I take pleasure in making it available to the profession in the hope that those members who are engaged in the field of ceramic research may find it of interest and possibly of some assistance to them in their work, from which I hope will soon be developed a disk insulator possessing greater mechanical and electrical strength than any such insulator at present available.

The laboratory results of several well known investigators, among whom are Prof. H. J. Ryan of Stanford University, and Mr. F. W. Peek, Jr. of the General Electric Company, have definitely determined the voltage gradient curves and electrical stresses existing in disk insulator assemblies consisting of a number of disks of the same type. Their results show that in an unshielded assembly of seven cap-and-pin type disk insulators with a voltage to ground of 61,000 volts, the voltage gradient curve will be as given in Fig. 1. From this curve we see that the potential drop across the various disks ranges from a maximum of 14,000 volts across the disk nearest the conductor to a minimum of 6500 volts across the third disk from the tower or grounded end of the assembly. Investigation has also shown that the voltage gradient for the third of the assembly nearest the conductor is greater than the gradient for the surrounding air that of the middle third of the assembly is approximately the same as for the air, and that of the top third of the assembly is less than that for the air. As a result of this condition there is a leakage of current from the disks of the lower third of the assembly to the air, and from the air to those of the upper third.

Now consideration of the facts that the leakage resistance is not uniformly distributed along the assembly, and that the various units and the surrounding air are subjected to unequal electrical stresses, resulting from the unequal potential drop across the various disks, would lead us to believe that the disk adjacent to the conductor should fail most frequently and that the rate of failure of each of the seven disks in the assembly should bear a definite relation to the intensity of the electrical stresses to which that particular disk is subjected. However, an inspection of the tabulated results given in Table I, II and III, covering nine years of actual operating experience, shows no such relation existing between the rate of failure and the electrical stresses to which the disk are subjected as determined in the laboratory. Indeed these tables show that with the exception of disk No. 2, disk No. 1, the disk nearest the conductor, has the lowest rate of failure in the assembly, and that with the exception of No. 2 disk this rate increases with the

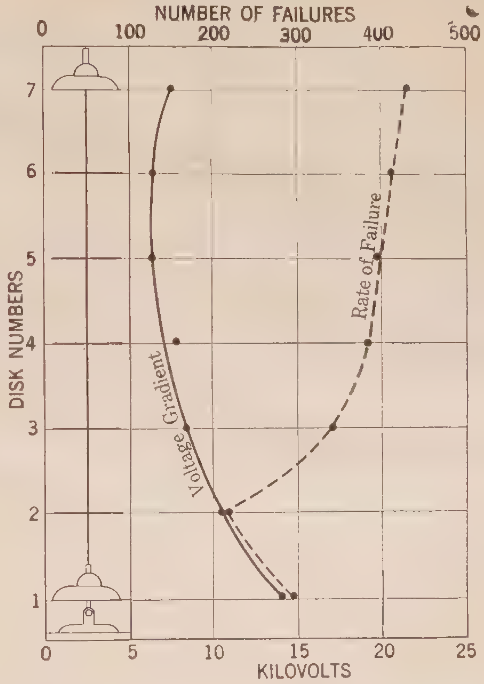


FIG. 1—VOLTAGE GRADIENT AND RATE OF FAILURE CURVES FOR SEVEN-DISK ASSEMBLY, UNSHIELDED
Line Voltage 105,000
Voltage to Ground 61,000

position away from the conductor until the highest rate of failure is found for the No. 7 disk this being the one attached to the tower. I would very much like to have someone more familiar than myself with insulator research and high-voltage phenomena furnish a theoretical explanation of the observed results as embodied in Tables I, II and III.

The tabulated results given in the three tables are based on the operation of a 100-kv. double-circuit steel-tower line 97 miles long during the period from March 1912 to October 1921.

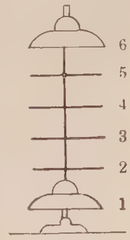
Presented at the Pacific Coast Convention of the A.I.E.E., Vancouver, B. C., August 8-11, 1922.

The principal physical features of this transmission line are: Double-circuit steel towers 73 feet high, supporting two three-phase circuits of No. 1/0, six-strand copper wire; The three conductors of each circuit are on the same side of the tower, the vertical spacing between these conductors is nine feet; the horizontal spacing of the two circuits is 15 feet for the bottom and the top conductors, and 21 feet for the middle conductors; as originally built the horizontal spacing of the two circuits was the same for a'l three conductors but so much trouble was experienced with the wires whipping together when snow or sleet fell off the line, that in 1916 the spacing between the middle conductors was increased to 21 feet by putting a three-foot extension on each end of the middle crossarm. The average span length is 680 feet. The disk insulators used are of the cap and pin type manufactured in 1911, and these insulators are consequently a product of the early days of disk insulator manufacture. When the line was built, six of these disks were used on suspension assemblies and seven on tension or dead end assemblies. However, so much trouble was experienced with these insulators failing on tension assemblies that in 1915 all cap and pin disks used in tension assemblies were replaced with tension assemblies made up of eight Hewlett disks, and the number of cap and pin disks used in all suspension assemblies was increased from six to seven; this insulation is used at present, although as seen from Table III, the rate of failure of the cap and pin disks is rapidly increasng.

TABLE I

Failures located on test from 1912-1915 arranged according to location of disks in the assembly, disk No. 1 being adjacent to the conductor.

Disk No.	Top Wire	Middle Wire	Bottom Wire	Total
1	15	18	37	70
2	6	10	25	41
3	11	14	21	46
4	13	13	16	42
5	10	11	17	38
6	24	14	12	50
Total	79	80	128	287



Cap and pin six-disk assembly

TABLE II

Failures located on test 1916-1921 arranged according to location of disk in the assembly, disk No. 1 being adjacent to the conductor.

Disk No.	Top Wire	Middle Wire	Bottom Wire	Total
1	112	112	100	324
2	101	96	90	287
3	193	204	135	532
4	246	203	147	596
5	237	210	181	628
6	259	211	186	656
7	281	239	212	732
Total	1429	1275	1051	3755

Cap and pin seven-disk assembly

Tables I, II and III refer only to the cap and pin disks used on suspension assemblies, there being on this line a total of 4452 such assemblies consisting of a total of 31,164 disks. The failures shown are only those located on our annual insulator test; failures causing cases of line trouble, which are invariably due to lightning, are not included as very often in such cases when three or four disks show signs of having been punctured the entire assembly is replaced. The information contained in Tables I and II is similar but it was necessary to separate it into two parts as the seventh disk added in 1915 was put in the position nearest the wire; the former No. 1 disc then becoming No. 2, No. 6 becoming No. 7 and so on. The small number of failures found in 1913, 1914 and 1915 is due somewhat to the fact that the tests made during these years were not as thorough as those that have been made in subsequent years.

TABLE III

Failures located on test from 1912-1920 arranged according to years and location of disks in the assembly, disk No. 1 being adjacent to the conductor. Total number cap and pin disks on suspension assemblies 31, 164, prior to 1916, 26, 712.

Disc No.	1913	1914	1915	1916	1917	1918	1919	1920	Total
1	14	26	30	54	51	41	42	36	294
2	8	22	11	21	20	44	22	69	217
3	8	22	16	20	48	63	40	124	341
4	9	23	10	26	44	85	60	127	384
5	5	14	19	30	55	88	67	116	394
6	3	23	24	21	52	88	40	160	411
7	..	..	..	43	71	103	42	170	429
Total	47	130	110	215	341	512	313	802	2470
% Total No. Disks	0.2	0.5	0.4	0.7	1.1	1.6	1.0	2.6	

Note: 1921 Figures not included in Table III.

From Tables I, II and III we find that the rate of failure for the position of the disk in the assembly instead of being greatest for No. 1 disk and then in the order Nos. 2, 3, 7, 4, 6, 5, which theoretical considerations as deduced from the voltage gradient curve in Fig. 1 would cause us to believe should be the case; actually occurs in the order Nos. 7, 6, 5, 4, 3, 1, 2. This would indicate that the longest life is to be expected from the disks nearest the conductor and the shortest from those at the tower or grounded end of the assembly. These results are exactly contradictory of the conclusions deduced by the writers of several recent articles based on their research work in connection with disk insulator assemblies.

Should further investigation and experience of operating companies show that the results embodied in Tables I, II and III are typical of the performance of disk insulators in service on high-voltage transmission lines over a period of a number of years, then it would appear that the present experimental efforts being made to distribute uniformly the leakage res'stance among the disks of the assembly, by us'ng shields grading the disks in the lower third of the assembly, or by other means, are misdirected energy and that the essential thing to be done is to devise some means which will increase the life of the disks in the top third

of the assembly and particularly that of the disk attached to the tower.

As previously stated, the cap and pin disks on whose operating pe formance the figures given in the tables are based were manufactured in 1911, and are there ore, undoubtedly inferior to the disks manufactured today, since the porcelains now produced are superior to those of ten years ago. However, this has no bearing upon the relative rates of failure of the various units in the assembly; since the only requisite for a fair comparison of these rates is that the disks used in the assembly shall be of uniform quality, and as all of the disks were manufactured by the same concern at the same period this should be the case.

In closing it may be of interest to state that in 1915 this company reinsulated several of its transmission lines, replacing the cap and pin disks with Hewlett type disks; and that the cap and pin disks removed were used to add an additional disk on some of the other lines, among them being the line concerning which the data given in the tables included in this article were collected. From this it will be seen that the disks added on this line in 1915 were not new disks but ones which had seen previous service. Before being installed in their new position these disks were given a thorough test, the General Electric oscillator being used to make this test. Out of about 5000 disks so tested over 700 failed, and in 90 per cent of these the failure was found to result from the puncture of the porcelain inside of the cap, or just at the edge of the cap. In these disks the cap is cemented on and the pin into the porcelain with neat cement, and as the coefficients of expansion of the metal cap and pin, of the cement, and of the porcelain are all different, it is my opinion that the so called aging and ultimate failure of these disks is primarily, a mechanical failure due to the gradual crushing of the porcelain inside of the metal cap by the varying compressive stresses to which it is subjected, these resulting from sudden temperature changes such as occur when a heavy shower falls on a hot summer day. Our experience with these cap-and-pin type disk insulators is that they deteriorate just as fast in storage exposed to the weather as when they are in service on the transmission lines.

Appendix

Table II revised to include 1922 test:
Test made June 1922

Disk No.	Top Wire	Middle Wire	Bottom Wire	Total
1	148	138	134	420
2	120	116	108	344
3	213	235	164	612
4	274	222	171	667
5	272	233	203	708
6	302	242	203	747
7	315	268	235	818
Total	1644	1454	1218	4316

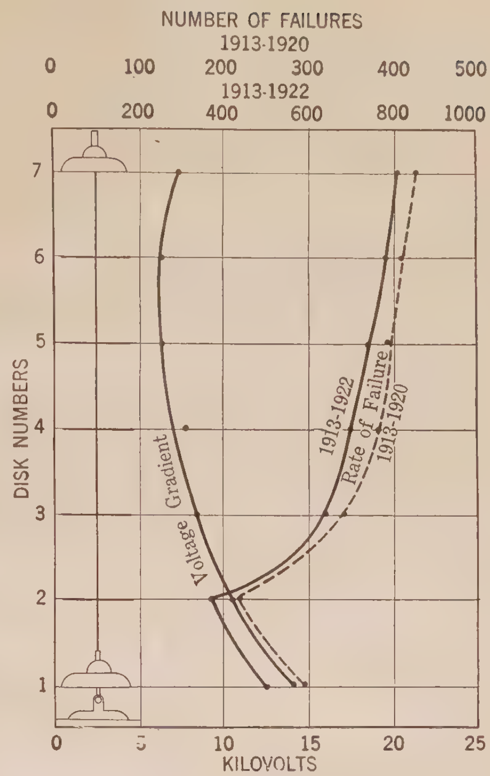


Fig. 1a—Revised to Include 1922 Tests.

Table III revised to include 1922 test: Test made June 1922

Disk No.	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	Total
1	14	26	30	54	51	41	42	36	100	96	490
2	8	22	11	21	20	44	22	69	111	57	385
3	8	22	16	20	48	63	40	124	237	80	658
4	9	23	10	26	44	85	60	127	254	71	709
5	5	14	19	30	55	88	67	116	272	80	746
6	3	23	24	21	52	88	40	160	295	91	797
7	...	...	...	43	71	103	42	170	303	86	818
Total	47	130	110	215	341	512	313	802	1572	561	4603
% Total No. Disks	0.2	0.5	0.4	0.7	1.1	1.6	1.0	2.6	5.1	1.8	

ELECTROLYSIS INVESTIGATIONS

During last month, the work of burying specimens of pipe in connection with the Bureau of Standards' soil corrosion investigation was completed in the territory west of the Mississippi River, and definite arrangements have been made for burying the last group of pipes in the states bordering the Great Lakes. Attention has been directed to starting chemical investigations that have a bearing on the soil corrosion research, and some of this work is already under way. This relates particularly to the study of the effect of the depth of burial on soil corrosion, a study of the effect of lime on both soil corrosion and stray current electrolysis, and an investigation of the possibilities of cathodic protection against both stray current electrolysis and soil corrosion.

Investigations have also been started in an attempt to throw light on the relation between the corrosion of iron and the physical structure of the metal.

Discussion at Midwinter Convention

LIGHTNING ARRESTERS[1]

From 1921 Annual Report of Protective Devices Committee—(HUNT) AND

ON DEVIATIONS FROM STANDARD PRACTISE IN LIGHTNING ARRESTERS[2]

(CREIGHTON) NEW YORK, N. Y., FEBRUARY 15, 1921.

Joseph Slepian: Mr. Creighton has explained very clearly the necessity for a high discharge rate in lightning arresters, if any real protection to electrical apparatus is to be obtained. If this high discharge rate path is also open to normal dynamic voltage, then, as Mr. Creighton points out, the large drafts of dynamic power which must be handled by the arrester makes it too large and costly to be practical. A clear case is thus made out for the valve type of arrester.

The electrolytic arrester is the most widely used valve type and has proven its great value in service. It depends for its action on rather obscure chemical phenomena taking place in thin films on electrodes in water solutions. It has disadvantages inherent with a water electrolyte, requires frequent attention, and sometimes trouble is experienced due to its sensitiveness to chemical impurities.

The recently introduced oxide film arrester also depends for its action on the chemical and electrical properties of a thin film. This film is dry, which is an advantage but like any other solid insulation, it may be somewhat slow in its breakdown under excess potentials.

For some time past, the company with which I am associated has been working on the problem of attaining the ideal valve type arrester, from the other end. That is, instead of starting with the chemical arrester, and trying to remove its disadvantages, we start with the simple spark-gap type of arrester and try to impart to it the valve characteristic. These efforts have been successful, and, as the results are now approaching commercial form, I believe it is of sufficient interest to briefly describe the principles utilized.

To have a valve characteristic, a gap must pass current when and only when the applied voltage exceeds a definite critical value. To be of practical use for lightning arrester purposes, this critical voltage should be of the order of at least several hundred volts. Now it is known that only low-current discharges n air require such high voltages to be maintained, hence an investigation of the volt-ampere relations in low-current discharges is suggested.

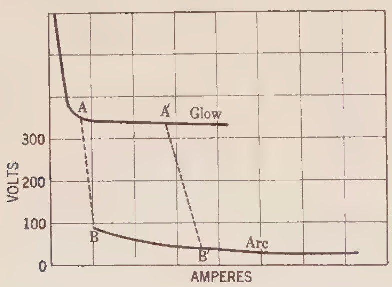


FIG. 1—ARC AND GLOW DISCHARGE

Fig. 1 shows the results obtained in such an investigation. For large currents, the ordinary arc characteristic BB' is obtained, with voltages from 20 to nearly 100. The arc issues from a brilliant incandescent cathode spot. As the current is reduced, a point is reached, B in the figure, where the rate of evolution of heat is insufficient to maintain the cathode hot spot, and the voltage and current suddenly jump to values lying on another curve AA'. This is the volt-ampere curve of glow discharge. By water cooling the electrodes, it is possible to carry the curve AA' beyond the point A, say to A', before the developing of a cathode hot spot, and the sudden dropping into the arc characteristic at B'.

In the arc there is an incandescent cathode spot with resultant vaporization of the electrode. If this hot cathode spot is prevented from forming, the discharge takes the glow form, and, with most electrodes, requires not less than 350 volts to be maintained. It is evident that a spark between cold electrodes must always start as a glow, and only after a spot on the cathode becomes sufficiently heated, does an arc form.

The curves in Fig. 1 show that it is not practical to try to get much more than 350 volts consumed in the discharge, and they also show that, if the cathode is kept cool, considerable current density may be passed still maintaining this voltage. The use of electrodes of high specific resistance offers a means for keeping the cathode surface cool for the lengths of time involved in surges on power systems. For if the resistance in series with any point is high, it is clear that the current flowing from any spot on the surface is limited, and so, too, is the heat involved. The energy in the discharge is not turned loose mostly at a small spot on the cathode, but is distributed all over the face of the electrode. Thus, no spot heats excessively, and the discharge remains in the glow form.

Having ensured that the discharge will require 350 volts for its maintenance, we must, if the desired valve characteristic is to be obtained, provide that the discharge shall also start at

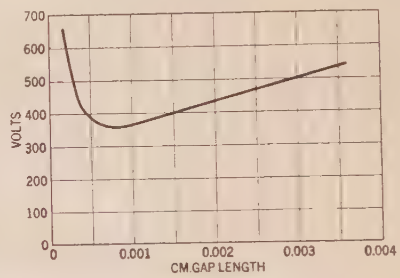


FIG. 2—SPARKING POTENTIALS FOR SMALL AIR GAPS

about 350 volts. At first sight, this seems a requirement impossible of practical attainment, because of the exceedingly minute gap necessary. But here again the high specific resistance in the electrode material comes to our aid.

Fig. 2 shows the relation between the spark-over potentials and gap lengths for plane electrodes, and very short gap lengths.

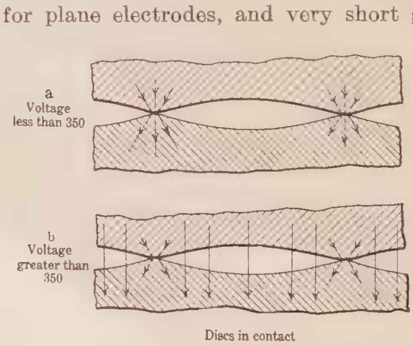


FIG. 3

It shows that the sparking potential reaches a minimum of a little over 350 volts for a gap length a little less than 0.001 centimeter, and that for smaller gap lengths, the sparking potential increases again. This may appear surprising to most of us, but it is well established by experiment.

Now suppose two disks of high-resistance material are laid one upon the other. (Fig. 3). With ordinary workmanship, th e

1. A. I. E. E. JOURNAL, Vol. XL. 1921, August, p. 687.
2. A. I. E. E. JOURNAL, vol. XLI., 1922, February, p. 99.

disks will make actual contact at only three or four points. Elsewhere, they will be separated by small air gaps, which may run up to three or four mils at their widest. Somewhere between the two extremes of the actual contacts, and the separation of several mils, will occur the separation of about 0.001 centimeter having the breakdown potential of about 350 volts.

When voltages less than 350 volts are applied to the disks, the current will pass only at the points of actual contact, and because of their constricted nature these current paths will be of exceedingly high resistance. Thus, very little total current will pass. (Fig. 3A). When, however, more than 350 volts is applied, the air gaps breakdown, and current is passed over the whole face of the disks. (Fig 3B). Thus, a very low over-all resistance is presented. The resistance in the electrode material forces the current to distribute itself uniformly. Hence there is no local heating, and the discharge remains in the glow form. When the voltage falls to less than 350, the discharge stops, and the current again falls to the very small value passed by the actual contacts.

To recapitulate, by the use of high-resistance electrodes, it becomes practical to use gaps so small that little more than 350 volts is required to break them down. Also the discharge which follows the breakdown is prevented by the resistance from concentrating at any point but must distribute itself over the whole face of the electrodes so that no local hot spot can form, with a resultant arc. Hence the discharge remains in the glow form, requiring over 350 volts to be maintained.

We have here then, an arrester of the valve type which has nothing whatsoever chemical in its principle of operation. It is as simple in its construction as the usual spark-gap arrester, and, in characteristics, parallels the electrolytic arrester. I believe that optimism as to the future of this device is quite justifiable.

Mr. Creighton suggests that the power factor of aluminum electrolytic arresters may be a reliable criterion of the extent of their deterioration. For several years I have been engaged in an extensive study of the power factor of aluminum cells, partly for whatever useful information might result for lightning arrester practise, and partly for the purpose of developing an electrolytic condenser for general power purposes. My experience makes me very doubtful if reliable conclusions can be drawn from the power factor as to the suitability, of a cell for lightning arrester purposes.

The electrical and chemical phenomena going on in the film on aluminum electrodes in an electrolyte are exceedingly complex, and apparently it is possible with different electrolytes to find any combination of the following properties in individual cells: 1. High power factor or low power factor. 2. Rapid dissolution or slow dissolution of film on open circuit. 3. Rapid corrosion or slow corrosion. 4. High charging current or low charging current. 5. Rapid formation of precipitates or slow formation of precipitates.

It is only the last four properties I mentioned which are significant for lightning arrester purposes, but the first is the one on which Mr. Creighton puts a lot of stress.

Actually it is possible to get any combination of all these properties in different electrolytes.

The only uniformity which I have noticed is that all cells which start with low power factor increase their power factor with time. This increase in power factor may or not may be accompanied by any considerable deterioration in respect to the properties (2), (3), (4) or (5). The only conclusion which can be drawn from high power factor is that of age, and little can be said about the properties which are more important for lightning arrester purposes.

As an example, in one electrolyte which I tried, the initial power-factor was 2½ per cent. The cell was connected permanently to the line and let run 24 hours a day. Here was a service thousands of times more severe than that which lightning arresters undergo. Nevertheless, the rise in power factor was very slow. The rise was inappreciable for the first two months, and after a year was only about 10 per cent. Judging by the power factor, here was an ideal lightning arrester electrolyte, but in respect to film dissolution, on open circuit it was quite inferior to the electrolytes now on the market.

Again, another electrolyte ran at about 6 per cent power factor, but the corrosion was so bad that the run was terminated in a few weeks. Still another electrolyte, although it gave low power factor, kept shedding precipitates of aluminum hydroxide until the cell was almost packed solid with them.

With respect to reestablishing the low power factor by electrolyte renewal, and electrode treatment, I also found matters very complex. A series of experiments indicated very clearly that the rise in power factor was due in large part to a change taking place in the film on the aluminum itself. By re-treating the aluminum in fresh electrolyte it was possible to return to the low power factor, but unless every trace of the old film had been removed, the power factor in the re-treated cell would rise again much more rapidly than it had done in the old cell. For example, if the power factor in the old cell had risen 10 per cent in a year, after re-treating the power factor would rise 10 per cent in a month or two.

I maintain therefore that great caution should be used in drawing conclusions from power factor measurements as to the suitability of aluminum cells for lightning arresters. Many tests over periods of many years will be necessary before confidence can be established in a power-factor criterion.

D. W. Roper: The great difficulty in making a few installations of a new type of arrester is in drawing correct conclusions from the results. Having attempted some investigations of lightning arresters myself and concluded that after a few years it was impossible to draw any accurate conclusions from an installation of 700 arresters, it does not appeal to me when the experience with one or two installations is used as a basis of some general conclusions on high-voltage arresters. However, if we can induce a number of engineers to cooperate in the same investigation on lightning arresters and to use the lightning arrester committee as a clearing house for *all* their information, and not selected portions of it, then we should be able, in a comparatively brief time to get some accurate conclusions.

Quite a large number of types of arresters are mentioned in one of the papers. Not all of them are mentioned. One letter tells about the horn-gap water-barrel combination successfully performing its functions. I wonder if it ever successfully performed the function of a lightning arrester.

The Standards Rules of the A. I. E. E. contain a definition of an arrester, and that is as far as the rules go, but the definition includes the requirement that it must limit the voltage across the apparatus at the time of lightning discharge. Some types of arresters accomplish that result very efficiently. The arresters which have a very large amount of resistance in series apparently do not, and in this connection, I think that some attention should be drawn to a description of the lightning generator, as it was called, in the article in the *General Electric Review* for November and December. This appeared to the speaker one of the most interesting devices brought forward in recent years for the testing of lightning arresters, and the results as given in these two papers are the results which can be used in comparing directly different types of lightning arresters. That is, the tests give a measurement of the maximum potential across the terminals of the arrester at the moment of discharge, which is exactly what is wanted, and the results obtained from that lightning machine appear to check very closely with the results of experience with the different types of arresters in service.

Referring again to the letter regarding the performing of the functions of the lightning arresters, there are quite a few types of apparatus which are called lightning arresters, and which are on the market, and some of which find a ready sale. Some of them will make a funny noise when there is a lightning discharge, and some will make quite an interesting sputtering arc, and you could make them so that they would ring a bell or operate an automatic counter, but they do not comply with the function of

a lightning arrester, that is, they do not limit the voltage across the arrester at the time of discharge. I suggest that the Institute might properly take some steps to protect the smaller companies who have occasion to use lightning arresters from the assaults of the glib salesman who sells these interesting, sputtering things called arresters, and which actually serve no useful purpose except to the salesman. The Institute might properly devise a performance specification for lightning arresters, and perhaps have a classification of types which would indicate the relative value of the various types of arresters, and then such a rule, with the backing of the American Institute of Electrical Engineers, would serve, you might say, as a blue sky law to prevent the sale of these lightning announcers to people who want lightning arresters.

J. L. R. Hayden: The deterioration of the aluminum arrester apparently is due to the current passing through it. This pits the cones and changes oil and electrolyte. It causes increase of current passing through. This still further increases the deterioration.

The total current in the aluminum arrester consists of a capacity current and an emergency current. The former does not pass through but merely into the arrester, and is harmless. It is the energy current which does the harm. The energy current normally is very small, compared with the capacity current, so that the total current is mainly made up of the capacity current. Therefore the energy current may considerably increase, without showing an appreciable increase of the total current. The total current may even decrease due to some loss of electrolyte which reduced the active plate surface. It requires a very great increase of energy current to show as an increase of the total current. It would therefore be reasonable to expect that the deterioration could be detected earlier, if the energy current could be measured alone. This is done by wattmeter measurement. Possibly direct-current measurements might do the same, as with direct current there is no capacity current.

The limitations of such method seems to me, that individual cells cannot well be measured, but only the whole stack of cells. The deterioration may be uneven. Only a few cells may have deteriorated, most are still good. Then the power factor of the whole stack would still be low and normal, but the arrester would be unsafe, as the few deteriorated cells heat and arc and thereby destroy the other cells.

As this method gives the average result of the whole stack, it can be useful only if the deterioration is fairly uniform through the whole stack. How far this is the case requires further investigation.

In the *OF* arrester, such measurement of deterioration by the energy current is more feasible, as in the *OF* arrester the capacity current is small, and most of the current is energy current. It therefore is our practise in life testing of *OF* arresters, to regularly measure the current and judge the deterioration from it. Individual cells can be measured. If in the cell the current is abnormally high, then the voltage on the cell is low, if it is in series with other cells. If the energy current is abnormally low—which also is objectionable in the *OF* arrrester,—then the voltage is high. Individual cells of the *OF* arrester therefore are tested by observing whether the voltage across the cell is within the proper limits. This is done in the standard method of service testing of *OF* arresters by the use of a neon tube connected across individual cells.

W. A. Lougee: An arrester to protect must have a sufficiently high current discharge rate, that is, its internal resistance must be low. Lightning arresters are one of the very few types of electrical apparatus which can not be tested and be thoroughly understood by the purchaser, and it is on account of this unfortunate situation that many incorrect ideas are obtained, and that many inefficient lightning arresters are in use.

I would like to take up a few points mentioned in the letters quoted in Mr. Hunt's paper. The oxide film arrester is spoken of as dependent on obscure phenomena and involving the action of films of very minute dimensions; also as a hair trigger device and based on fine haired theories and obscure chemical reactions. The best answer to all this is to state briefly the arrester's action and behavior when connected to the lightning generator that Mr. Roper mentioned.

With this apparatus, we have been able to obtain a greater discharge through an arrester than the arrester will be subjected to in actual service, outside of a direct stroke. A piece of a tree branch placed in the circuit of this lightning generator will be splintered and torn to pieces. Now if an oxide film arrester is substituted for this tree branch, and, in addition the normal voltage of the arrester be also applied directly to the terminals from a circuit of large power capacity, the high power impulse discharge is successfully taken care of. That is, not only does the impulse go through the arrester without damage to either the dynamic circuit or the arrester, but the recovery or reseal action of the arrester prevents any dynamic power following through the arrester. It is evident to withstand such punishment, the arrester must be staunch and not a hair trigger device.

Another writer mentions the fact that only one of sixteen oxide film arresters discharged. Obviously, this is absurd unless one sits by the arrester and watches it continuously as the arrester itself gives no external indication of discharges.

Lightning arresters are not hot-house plants. They are given a more severe testing in the factory than the majority of electrical apparatus and they will stand a lot of abuse.

Reference was made to the possible high time-lag of the oxide film arrester due to the fact that it consists of solid insulation. The film is solid, but at the same time it is somewhat porous. An oxide film arrester on the circuit without a series gap will pass several milli-amperes of current, and it is on this account that it has not a high time-lag.

L. R. Lee: The writer is interested in lightning arresters from the standpoint of the construction and operating engineer, and in going over this matter of arrester with users, he has found that there is, as mentioned in this paper, some lack of confidence in the use of the lightning arrester. Papers like this should help in restoring some of this lost confidence as they give the user a better insight into the functions of the arrester, the way it performs and some simple tests by which he can convince himself of the value of the arrester as a device to limit the damage that may be caused by high voltage. I think that the account given about the arrester which went some thirteen years without being opened is interesting but I doubt the advisability of giving publicity to such examples. I would much rather hear about arresters that have been systematically repaired twice a year by opening the arrester and giving thorough inspection, and how this was accomplished at small cost and little inconvenience. I believe some of the lack of confidence has been due to lack of proper maintenance.

I do not believe the construction and the operating engineer are in a position to offer any valuable suggestions as to the way arresters should be built, it is their function to see that they are properly installed and maintained. It is up to the manufacturer to collect all possible data from the operating and construction engineers as to troubles or difficulties which they may have encountered in the use of arresters and make all possible use of such data in making progress in the design of this equipment. I doubt whether there could be too much emphasis placed by the manufacturer upon the proper care of the arrester and the proper way of installing it.

It is not only important that the manufacturer point out on the wiring diagram the location for the arrester but he should also advise with the construction engineer as to the physical arrangement of the connections for the arrester, and in planning for the installation of the arrester thought should be given to any trouble which may occur from the use of the arrester and also to the accessibility and convenient arrangement that may facilitate inspection and repair.

I realize that the manufacturer has been loath to lay down too

rigid rules for the maintenance of this equipment, and I realize his good intentions of working out ways of testing the equipment so that it may not be necessary to disassemble it, but it seems to me quite natural to expect confusion on the part of the operating engineer when he is told about tests which may indicate to him the condition of his arrester and at the same time told that these tests may not work and that the arrester should be overhauled in any case. I believe it would be better to spend any effort along this line towards making it easier and cheaper to open the arrester and give it thorough inspection and such repair as may be necessary.

The writer has been much pleased to note the progress being made in the oxide film type of arrester as it seems that this arrester working on a similar theory to that of the electrolytic, is a device much simpler and easier repaired and altogether seems to have many advantages.

QUESTIONS ON THE ECONOMIC VALUE OF THE OVERHEAD GROUNDED WIRE*

(Creighton), New York, N. Y., February 16, 1922

W. W. Lewis: In this paper Mr. Creighton draws the conclusion that the overhead grounded wire is in general a detriment to a semi-insulated or high resistance pole line structure. By this I understand that he means not only the horizontal continuous grounded wire but also the vertical grounded wire that is applied to individual poles.

I believe that the experience of operating companies in general will not bear out this conclusion. While it is true that there has been considerable trouble on some systems due to the overhead grounded wire, this has been mainly on account of the fact that the ground wire was not put up with the same care and idea of permanency as the power conductors, with the result of breakage, and interference with the conductors. Also in some cases the insulators were small for the voltage and the presence of the ground wire further reduced the factor of safety. Where the ground wire is adequately installed and the insulators have a reasonable factor of safety, I believe that the ground wire is of great benefit in protecting the insulators and poles. The testimony of a few power companies in this respect will be interesting.

The Southern Power Company have overhead ground wires on practically all of their 2200 miles of 100,-44-and 13-kv. lines. It is their belief, based on experience, that ground wires afford considerable protection from lightning disturbances. The ground wires increase the mechanical stability of both pole and tower circuits and in case of pole lines prevents splitting of the poles by lightning.

The Idaho Power Company has had considerable trouble with overhead ground wires due to mechanical difficulties and is not putting them up on new circuits, in fact has removed them in some cases. However, it has had considerable pole shattering where lines were not protected by ground wire and has cured this by grounded bayonets at the individual poles. Its experience has led it to favor this class of construction.

The Utah Power and Light Company make a practise of placing a metal band around the tops of its wooden poles and grounding this band. The conductors are in general arranged in a triangle with the top wire supported by a pin carried at the top of the pole. Wooden pins are used. Its experience with this construction has led it to believe that it has averted numerous cases of shattered poles and broken insulators. Operation without the metal band grounded, led to many cases of shattered poles. This construction cannot be used if the insulators are inadequate, as it will lead to shattering of insulators. Practically all of its 475 miles of 44-kv. line is equipped with the grounded metal bands, which its experience has led the company to favor.

Other companies have reported similar experiences which is contrary to that predicted by Mr. Creighton. A questionnaire directed to these operating companies would no doubt elicit a great deal of valuable information along this line.

C. L. Fortescue: On my trip last year to the Pacific Coast, I had some questions asked me about the grounded wire for protection, and I also elicited a good deal of information about it. A questionnaire was sent out recently by the N. E. L. A. in which experience with the grounded wire was asked. A number of people told me that the questionnaire was not always treated seriously, that the replies could not be depended upon, and that a lot of the companies that were questioned about the use of grounded wires had never installed grounded wires properly.

This seems to agree with the statements of Mr. Lewis. Where grounded wires have been properly installed, they have given a good deal of protection, I believe.

Mr. Creighton's theoretical explanation of the grounded wire, I think is not quite adequate. The grounded wire is used to increase the capacity of the transmission system as a whole to ground, so that if there is a charge induced on the system, when the charge is released as for instance by the discharge of a thunder cloud, the potential of the surge will be limited in value in inverse proportion to the capacity. Any means which increases the capacity of the system as a whole to ground, will give correspondingly lower potentials, due to lightning effects. I was talking to the engineer of the Byllesby Company some time ago about the use of grounded wires, and he told me that his company was going to continue their use, and he thought they did good. He said that according to the general method of putting up a grounded wire it was considered as something that could be stuck up in any way at all. According to his ideas the same class of construction should be used for installing a grounded wire as in the case of the transmission lines themselves, and that if this practise were carried through, with proper maintenance, the protection obtained was good.

E. P. Peck: Dr. Creighton referred to a case which came up recently regarding the use of an overhead ground wire in a small system in New York State. The president of the Company operating that system had been ordered to install an overhead ground wire in connection with a 13,200-volt circuit which had been reported as giving adequate service without the overhead ground wire. The president objected to installing the overhead ground wire, and he wrote a large number of letters to most of the representative companies in New York State, and also to a number of large transmission companies and management corporations throughout the country. The gentleman was kind enough to send me a copy of all of the letters, which I very carefully reviewed. Of the 78 replies to his questionnaire, 72 were against the use of overhead ground wires, 2 were non-commital, and 4 were in favor of overhead ground wires on transmission lines. I was very much pleased to find that the concensus of opinion as shown in these letters were so overwhelmingly against the overhead ground wire, because they confirmed my operating experience. Had the questionnaire been sent out ten years ago, I dare say the majority of the opinions would have been favorable to the overhead ground wire, as a good many theoretical considerations would indicate that the overhead ground wire is of considerable value. My operating experience, however, has caused me to very definitely decide that the overhead ground wire is a source of trouble.

On one line in the South, which was equipped with an overhead ground wire, we had a large amount of trouble. The line was re-insulated and at the same time the ground wire was removed. After the re-insulation the line gave practically no trouble, and we concluded that the ground wire had not done any good, in fact indications showed that the presence of the ground wire caused considerable additional burning to the cross-arms and pins. Since that time, and in connection with a number of different lines, the same experience has been repeated to a greater or less extent. We do not now put an overhead ground wire on

*A. I. E. E. Journal, Vol. XLI, 1922, January, p. 21.

wood pole lines under any conditions, and probably never will unless some new evidence comes up.

Our results indicate that the overhead ground wire does more harm than good, not due to its falling or breaking, but due to the fact that it puts ground potential close to the conductors and reduces the insulating value of the wood pins, cross-arms and poles.

In Utica we put up several transmission lines of intermediate voltages without overhead ground wires. On these lines we have had only one pole shattered, that I recall, in two years. The insulators were not damaged and the pins and cross-arms were not burned. We have not lost a single insulator on these lines. On the other hand we have lost something like 15 insulators, due to flash-over, on our steel tower lines equipped with overhead ground wire, in about the same period, though the steel tower line is insulated with excessively large insulators which had not been in service as long as a year at the time of the failure.

It is my definite opinion that the overhead ground wire on wood poles does more harm than it does good.

C. P. Steinmetz: The great value of Dr. Creighton's paper, in my opinion, consists in the very complete review and discussion of the function of the overhead ground-wire. While I thoroughly agree with all the facts brought out by him, I am sorry to say that I must somewhat disagree with the conclusions drawn therefrom.

I am fully convinced that the overhead ground-wire, when properly installed in a transmission system, is a most effective and a most valuable protective device.

I believe it is necessary to protect a station by adequate lightning arresters, and the failure to install lightning protection at the station is economically inexcusable. Nevertheless, if I were given the choice between the use of the overhead ground-wire, or the use of lightning arresters in the station without the overhead ground-wire, I would rather take my chances with the overhead ground-wire and no lightning protection in the station than to attempt to run without overhead ground-wire with all the lightning protection of the station that it would be possible to give, although neither of these plans is economically defensible, but both, ground-wire and lightning arresters, in my opinion, are necessary and are supplementary to each other.

The advantage of the ground-wire is that its function is preventive, while that of the lightning arrester is merely curative. The ground-wire keeps the high-voltage disturbances out of the system, those disturbances which might enter from the outside, by lightning, etc., or originate in the system, while the lightning arrester discharges such disturbances as have entered the system. Theoretically, therefore, either should be sufficient by itself to protect the system. Unfortunately however, neither of the two is complete in its action. The overhead ground-wire does not completely keep out abnormal voltages, but the best we can expect is that it reduces the over voltage of the disturbance, which, entering the station has to be discharged by the lightning arrester.

Unfortunately, the lightning arrester must have a spark gap in series with the discharge circuit, which must be set for a voltage materially in excess of the line voltage, so as not to interfere with normal line operation, and this is a limitation of the protective value of the lightning arrester, and every discharge of the lightning arrester, to some extent, means a shock to the system, and therefore it is desirable to reduce the work put on the lightning arrester as much as possible by the overhead ground-wire, and so getting the higher safety resulting therefrom.

In my opinion the two most important functions of the overhead ground-wire are, first, that it reduces the voltage electrostatically induced in the transmission line as the result of the bound charge on the line, produced by the charge of the thundercloud, or electro-magnetically as direct induction from a lightning flash overhead. When calculating this effect we invariably get rather disappointing results, that is the total effect is not more than 20 to 40 per cent voltage reduction at the most, and my conclusion and that of other observers is rather that the protective value of the overhead ground-wire is materially more than would be indicated by the reduction of the voltage due to its use.

The explanation therefore seems to me the following: For some years I have studied the phenomenon of the thundercloud, and from whatever data I gathered, to get an idea of the actual voltage of the thundercloud and the lightning flash, its current value, etc., my conclusion rather is that in the average the voltages induced by the thundercloud in transmission circuits are not very materially above those which the transmission line insulation would stand momentarily. With many of the induced lightning disturbances not much above the disruptive strength of the line, the result would be that a moderate reduction of the lightning voltages such as given by the ground-wires, would very much increase the safety of the system, out of proportion to the percentage of reduction, especially as not only the voltage, but also its duration is reduced by the ground-wire.

Thus it may be that a reduction of the lightning voltage by 30 or 40 per cent would, in view of the time lag of the circuit insulation, reduce the number of failures perhaps by 80 or 90 per cent, depending on conditions.

The second protective action of the ground-wire is its damping effect on any wave or other disturbance traveling along the line, by its action as a short-circuited secondary. The ground-wire must consume considerable of the energy of a traveling wave in the transmission line, and thus greatly increase the energy dissipation of the traveling wave, especially when it is considered that most of these ground-wires are steel cables, which have a large high-frequency resistance.

The result hereof would be that when using a ground-wire, only those disturbances, atmospheric and otherwise, which originated near the station, would reach the station with serious amplitude and dangerous voltage, but anything happening further out on the line would be sufficiently dissipated, or reduced in intensity, that when it reaches the station it is of negligible magnitude. I believe in this consists one of the main protective values of the overhead ground-wire, that it practically frees the station from any serious disturbance which occurs in the line at a considerable distance from the station, and requires the consideration only of those disturbances which occur nearer to the station, which are of a rather lesser number.

There also would be a certain action resulting from the energy dissipation which protects against the line building up standing waves or cumulative oscillation by arcing grounds, etc., in the transmission wires. That, however, is probably not of such great value, because the resistance of the transmission wire, is usually sufficiently high to limit the building up of a stationary wave. It is only in very high-power circuits where the line resistance is very low that there may be some danger of the building up of destructive oscillations. The two main features, in my opinion, are the screening effect tending to keep disturbances out, and the energy consumption rapidly dissipating disturbances, and these fully justify a properly installed overhead ground-wire in long distance transmission circuits.

W. S. Jones: In a paper presented at the meeting of the Institute at Washington, D. C. in 1914, Mr. L. A. DeBlois stated certain conclusions which were determined as a result of tests made by him in connection with the investigation of lightning protection for buildings. These conclusions appear to be pertinent to the subject under discussion and are quoted as follows:

"(a) All conducting surfaces not thoroughly grounded, when exposed to the influence of a charged cloud immediately overhead, acquire a potential against ground which increases with the height of the conducting surface above ground.

(b) A difference of potential will exist between all conducting surfaces not bearing the same average spacial relation in the electrostatic field to ground or to nearby grounded objects.

Such average spacial relation is determined by their shape and size as well as distance from ground or grounded objects.

(c) Conducting surfaces in a vertical plane which would acquire practically no potential from their position in the electrostatic field may acquire a charge from the influence of adjacent objects.

(d) The grounding of a conducting surface generally increases the danger of sparks from adjacent non-grounded surfaces.

(e) Interconnecting adjacent conducting surfaces can prevent differences of potential between them but may increase the tendency of the lowest surface (relative to ground) to arc to ground.

(f) Discharges tend to take the shortest path, and large surfaces in the horizontal plane should be interconnected or grounded at more than one point.

(g) A grounded roof acts as shield for objects beneath it and even when poorly grounded diminishes the potential between them, but potentials can be introduced below it by conductors which extend inward from the outside, provided they are of sufficient capacity.

(h) Secondary discharges may occur from the sudden charge of an overhead cloud or from its discharge. The discharge in any case follows the natural frequency of the circuit and consequently may become oscillatory, though this condition is improbable in the ordinary interior apparatus, excepting only electrical equipment.

(i) The effect of adjacent lightning rods is to diminish the intensity of secondary effects, though for outside rods of reasonable height and spacing, the 'secondary static protective-ratio' is practically inconsiderable."

If these conclusions still hold true, and I believe that they do, the overhead grounded wire does not adequately safeguard the line against lightning on account of the induced secondary effects and the reluctance, on the part of a lightning discharge, to follow horizontally along an aerial conductor.

I believe that in such cases, where overhead grounded wires are used, a much more effective and satisfactory arrangement would be to provide a grounded aerial point at each pole were it practicable to extend the point to its proper height. This, however, appears to be a problem from a mechanical standpoint.

It is my opinion that the only effective means of protection against lightning and surge disturbances is the use of electrolytic arresters, or others equally as sensitive and as efficient, at frequent points along the line.

R. H. Marvin: This paper performs a valuable purpose in pointing out that before deciding either for or against the ground wire, that consideration must be given to the functions it is supposed to perform and the need for so doing.

There are few subjects on which experimental data are so scanty, difficult to obtain and to interpret when found.

In the case of wood pole lines it would appear that not enough importance had been attached to the effect of the high resistance of the pole. It is generally admitted, that with the possible exception of a direct stroke, the actual lightning discharge over the surface of an insulator is harmless. The damage is done by the dynamic or power arc which follows it. It is common practise in the laboratory to use high resistances in series with sphere gaps. The resistance does not effect the break-down voltage but does prevent a heavy current and injury to the spheres. Another good illustration is the horn gap arrester with high resistance. The value of such arresters is debatable, but its strongest enemies will admit that it does protect itself. This is well brought out in the recent "Questionnaire on Lightning Arresters" where one reply after describing the destruction of a modern type of arrester states, "I am positive that a water barrel horn gap style of arrester, as above suggested, would not have been injured."

The wooden pole gives this important feature of a high resistance between each insulator and the ground. There is not much known about high-voltage arcs, but it is probable that they follow the same general principles as the shorter low-voltage arcs. If this is so it can be shown that for any given arc length and pole resistance there is a definite minimum voltage necessary to maintain an arc. If the voltage is below this value, the arc cannot hold. It is probable that in many cases insulators on wood pole lines without ground wires flash-over from lightning, but owing to the high resistance of the pole no arc forms and no damage results. The particular point I would bring out is that it is not so much the induced lightning discharge we wish to prevent or avoid, but the destructive effects of the dynamic power arc.

This action is confirmed by several cases which have come under my observation. In the first instance, a 33,000-volt line with wood poles, metal arms and overhead ground wire gave excessive trouble from flash-overs. By mounting the ground wire on insulators and bringing the ground connection off in such a way as not to ground the metal arms, the trouble disappeared. Another 33,000-volt system having also metal arms on wood poles experienced numerous flash-overs and shut-downs on the parts having a ground wire, but none on a short section where the ground wire had been omitted.

Discussion at Chicago Convention

ELECTRIC POWER APPLICATION TO PASSENGER AND FREIGHT ELEVATORS*

(Reed,) Chicago, Ill., April, 21, 1922

H. D. James: The selection of the proper size elevator car and the proper speed of operation is very essential for the success of any installation. The tendency is to use car speeds of 500 to 600 ft. per min. on the larger installations and even higher speeds have been tried out in practise. The tendency in New York City towards very high buildings of the tower construction may lead to elevator speeds of 1000 ft. per min. or even more.

In selecting an elevator speed, consideration should be given to the distance between stops. In an ordinary office building an elevator operating at 600 ft. per min. will have to travel at least two floors to obtain full speed for even a very short part of that travel. The power consumed during acceleration is an important part of the total power consumption so that the cost of operating at 600 ft. per min. in a low rise building may be out of proportion to the benefits ordinarily obtained, unless an improved method of control is adopted.

The more rapid the rate of acceleration, the greater the advantage obtained from high-speed elevators. If the acceleration curve is the correct shape a very rapid rate of acceleration is just as comfortable as a slow rate. The human being feels the rate of change of acceleration more than the actual rate of acceleration. The correct curve can be obtained by using the second derivative of the speed-time curve. The use of the direct 1/1 traction elevator machine which eliminates all gearing is an important factor in obtaining a rapid rate of acceleration without discomfort to the passengers.

In accelerating a motor using a rheostatic controller the resistance in circuit with the armature is changed in definite steps which tends to cause abrupt changes in motor torque. One way to reduce this effect is to provide inductance in the circuit. Every electric circuit including a motor, has some inductance but this is small and a large number of controller

*A. I. E. E. Journal, Vol. XLI., 1922, January, p. 57.

steps are required to avoid a disagreeable acceleration. A large number of controller switches in themselves decrease the rate of acceleration as time is required for manipulating these switches. It is true that improved operation can be obtained by slowing down the operation of certain switches, but there is a corresponding necessity for speeding up the contactors in other parts of the control. A better way to obtain the desired result is to introduce additional inductance in the armature circuit. If this inductance has the correct value few contactors are required in the control circuit and the acceleration curve can be adjusted to conform very closely to the theoretically perfect curve. An important advantage in using the correct inductance is that when once adjusted the smooth operation of the car is not interfered with by minor changes in the time element of the individual contactors caused by the accumulation of dirt, change in friction, atmospheric conditions, etc.

Recent improvements in elevators have been obtained by the use of a variable voltage system of control. The older and more common control known as the rheostatic, is operated from a constant voltage system, the voltage across the motor armature being varied by changing the resistance in circuit. The variable voltage system directly changes the voltage of the generator supplying the elevator motor and no rheostatic control is required in the armature circuit. Briefly, the system consists of an individual generator for each elevator motor. The armature of the motor is connected directly to the armature of the generator and this circuit is not opened for normal operation. The direction and speed of the elevator motor is obtained by changing the direction and strength of the generator field. The only rheostatic losses are those of the field rheostat in the generator circuit.

This variable voltage system of control is inherently smooth in operation, as the field strength of the generator does not change abruptly giving the effect of an infinite number of control steps. By properly proportioning the field winding of the generator, a very high rate of acceleration may be obtained following the theoretically correct curve for acceleration and deceleration. This system of control will permit an acceleration from rest to 600 ft. per min. in very close to two seconds. It permits elevators to be operated by a-c. or d-c. power circuits as the motor-generator set can be driven by either a d-c. motor or a polyphase or single-phase a-c. motor. The a-c. driving motor may be a synchronous motor adapted for power factor correction where conditions require such an arrangement.

The power required when starting and operating at low speeds with the variable voltage system of control is less than with the rheostatic in the proportion that the generator voltage bears to the line voltage. For instance, if the generator voltage is 25 per cent of the line voltage, the elevator motor can draw approximately four times its full-load current without exceeding the full-load demands from the line. This is particularly valuable where the source of power is alternating current. Alternating-current motors during acceleration take a current equivalent to two or more times the full speed value. With the variable voltage system of control, the power demand during acceleration may be less than full load.

Where 500 or 600 ft. elevator speeds are used with the variable voltage system of control, the cars may be operated at reduced speeds with very little loss in efficiency, whereas with the rheostatic control, the power taken from the line is not reduced when the elevator speed is cut down.

In making a landing with a rheostatic controller the car speed may vary over a range of 3/1 or 4/1, depending upon the loading in the car, as the low speeds with this system of control are obtained by the use of armature series and armature shunt resistors, the voltage across the motor armature changing with the load. The variable voltage system of control can be designed to give close speed regulation at all speeds independent of the load so that the operator in approaching a landing can rely upon a definite car speed. This enables him to make his landings with greater accuracy and materially reduce the time consumed at landings. The accuracy with which low speed control can be obtained independent of the load with this system permits stops at either limit of travel to be accurately set, insuring greater safety of operation.

The magnet released friction brake used on elevator machines ordinarily functions to hold the car at the landings, the slowing down being accomplished by dynamic braking. If the friction brake is set abruptly, it causes a rough stop. In order to insure a smooth stop the tendency has been to ease up on the brake shoe so that the retarding effort of the shoe may not be much in excess of that required to actually hold the car at the landing. This is a dangerous tendency as the brake is intended as one means for emergency stopping. For that reason the brake is released by a magnet and applied by springs. If the brake is to be considered one of the safety means for stopping the car as well as holding it at the landings, the torque of this brake should be sufficient to stop within reasonable limits a fully loaded car travelling down at full speed, or an empty car traveling up at full speed. This introduces difficulties in the design of the brake as the torque required to bring the loaded car to rest within a reasonable distance may be sufficient to cause a rough stop under normal operating conditions. It is, therefore, necessary to proportion the windings of the brake so that the shoes are gradually, though quickly, applied. The best way to accomplish this is by means of magnetic induction, as a mechanical dash pot of any kind may stick fast and thereby introduce a hazard.

I would like to say a word about the high-speed geared elevator in comparison with the direct traction machine. It is well known that the efficiency of a low speed d-c. motor is inherently less than a high speed motor of the same rating, and this argument has been advanced as a reason for using a geared machine. Unquestionably there is a lower limit to the car speed which can be obtained with a direct connected 1/1 traction machine and, therefore, it is necessary to use a gearing for low speed elevators. The gearing may consist of a 2/1 rope hitch on the car giving half normal speed, or it may consist of some form of worm or spur gearing. The 2/1 rope hitch introduces additional friction losses and increases the wear on the rope. It, however, does not involve maintenance of the gearing and is an advantage from that standpoint.

All mechanical gearing has some clearance between the teeth. The high speed gearing for the steam turbine drive of ships reduces this clearance to a minimum by various mechanical expediences which, so far as the writer knows, have not been applied in the elevator field. The objection to clearances in the gearing for elevators is the lost motion when the torque is reversed. If the gearing is accurately cut and carefully adjusted, this lost motion may not be objectionable when the machine is first installed but the tendency of all gearing is to wear and wear increases the back-lash. Worm gearing requires thrust bearings to take the end thrust on the worm. The clearance required for this end thrust and for the teeth of the gearing introduces a difficult problem with high car speeds. Low speed elevators may be accelerated and decelerated at a relatively slow rate but high speed elevators require rapid acceleration in order to obtain the full advantages of high car speeds; this rapid acceleration and deceleration increases the difficulty of maintaining a geared machine in satisfactory operation.

If we assume that the overall efficiency of the high speed geared elevator can be made equivalent to the gearless machine we still have the advantage of eliminating all mechanical gearing which at best is a potential source of trouble. Where geared elevators have been installed in office buildings to operate at high car speeds, it would be interesting to know their rate of acceleration and deceleration; also how much the clearance in the gearing has increased after five or six years of service.

H. P. Reed: Mr. James suggests that the use of a gearless elevator machine is an important factor in obtaining a rapid

rate of acceleration without discomfort to the passengers. It would be interesting to have Mr. James explain this, for it is not understood why the gearless elevator can have any advantage over the geared machine in this respect.

The discussion included a statement that a large number of contactors decreases the rate of acceleration. This all depends upon the inherent characteristics of the contactors. They can be designed to give quick, smooth operation without the necessity of making some contactors slower than others. With correct design of contactors the time element will not vary, but will remain constant indefinitely regardless of atmospheric conditions.

Mr. James says that with rheostatic control, the slow car speed will vary over a range of 3-1 or 4-1, depending upon the loads. This is probably true of rheostatic control of a single-speed motor, but is not true of one having a wide speed variation by shunt field control.

Undoubtedly Mr. James' remarks on the variable voltage system of control will be received by engineers with much interest. The two possible objections to this system are, first, the difficulty of "teasing" or "inching" for an accurate landing, and second, that the all-day power consumption may be higher than with other methods.

Mr. James points to the lost motion between worms and gears as an objection to the geared elevator. If the elevator machine is properly built, this lost motion does not exist and high speed geared elevators have been in regular service for many years without this lost motion developing. The probable life from a satisfactory service standpoint of the elevator worm and gear, is in the neighborhood of 15 to 20 years. The maintenance of the worm and gear is not a serious item. It has been proven by actual comparative tests that the d-c. geared elevator with a 3-1 motor shows power economy over the gearless elevator on any installation requiring not less than 50 stops per car mile.

David Lindquist: In the large expensive buildings being erected today, the whole venture may prove a success or a failure depending on whether you have adequate or inadequate elevator service. It is therefore of utmost importance to be able to predetermine the service conditions and the service requirements, because only by doing that properly can a satisfactory and adequate elevator equipment be installed.

In other words, the first, and most important thing is to provide adequate elevator service in a building. Second, you have got to provide reliable service. In other words, maintain such service under the most exacting and most severe operating conditions. Third, you must provide elevator service that is reasonably economical. Fourth, you have to have the quality of service. In other words, smoothness of operation, easy access to the car and egress of passengers, ease of handling, etc.

Mr. Reed's excellent paper calls attention to the necessity of taking the operating requirements or the service requirements of the building into account. Unfortunately, however, I feel that he hasn't sufficiently warned you against taking average figures, average data, and applying those to specific conditions. While the human beings are considered, and have been called "unit packages of freight," they are by no means unit packages or standardized as far as their size and shape is concerned, and when you come to the mental attitude and the psychology, then you will find even greater differences than the physical differences of size and shape.

The psychology of it is more important than anything else, because you will find that in certain buildings handling a certain crowd your average constants we will say for loading and unloading the car don't hold good at all. In other words, the average constants may give entirely too long a time. In other cases it is entirely too short. Take the hired help part of a modern office building today and you will find that you can handle them faster and more efficiently than most any crowd. On the other hand, in hotels and department stores, you have an entirely different situation. The majority of the patrons will not be of the rushing kind, and therefore you have got to allow entirely other time constants for handling passengers of that kind. Some of the figures mentioned in Mr. Reed's paper are averages, and no doubt good averages, but I warn you against applying those specific figures for special cases.

In connection with speeds and capacities, Mr. Reed mentioned 700 feet as very nearly the maximum speed. Mr. James pointed out that at the present time the tendency, particularly in New York and for high buildings, is toward much higher speeds. As a matter of fact, a thousand feet speed mentioned will probably not be the limit in the near future.

Now regarding passenger service in office buildings, Mr. Reed has given a table, giving the relation between rise in feet and suitable car speeds. Those figures are good averages, but may, under specific conditions, and in many cases, be considerably modified in order to suit the requirements.

Mr. Reed further mentions that for automatic push button service 300 ft. per min. is considered at the present time the speed limit. That is true with the method of push button control that has been used in the past, where one passenger has absolute control of the car to the exclusion of all the rest that may want elevator service.

Now push button controlled elevators have quite recently been very materially modified, particularly in reference to the method of control and the operating conditions. The method of controlling is substantially the same as with the car switch operated elevator, except that no car switch is required, and that the car stops in the direction in which it has been initiated at the desire of the passengers. In other words, there is no signal system except indicating that the car is going to stop at the landing, but no signals to the operator, and no operator in the car in many cases.

At the present time there is being installed in New York City an elevator installation utilizing full automatic push button control for 700 ft. per min., in a high class office building. The reason for that is not to slow down the service and get less service, but to increase the rapidity of service or the volume of service as well as the quality of service with a certain number of elevators over what could be obtained with car switch control at the same maximum speed of 700 ft. There will be a man on the car, merely a guard. His functions is principally pressing the buttons as floors are called out by the passengers in the car. In any sequence, depending upon how they call the numbers of the floors, in other words, they may call 17 first, 13 next, and 19 next, but in any sequence at all, the elevator will stop in proper sequence.

At the same time, assuming, for example, that the elevator is ascending, in case a passenger on any floor wishes to go in the up direction, the car will automatically stop for him in the up direction, without the operator or the guard in the car even knowing about the fact that the signal has been set or the stop has been set for the elevator.

Now that condition is somewhat modified by the control arrangement. An elevator may be in the up motion at the third or fourth floor. This elevator may be signaled to stop at the 19th floor for a passenger. In such a case that elevator is considered too far away from the 19th floor, so, therefore, the first elevator that reaches the 19th floor will stop there, although it hasn't been dispatched by the guard in the car to stop there.

On the other hand, if an elevator has been dispatched by the guard to stop at a certain floor and that particular car is waiting say four or five floors from that particular floor, then this mentioned elevator would stop at that floor, not only to let out passengers, but also to take on passengers, and all the other elevators that may be active will not get the signal to stop there. By that method the number of stops required for

a certain service is materially reduced. You no doubt have noticed that frequently a car comes up, stops at the floor to let out passengers, and another car stops on signal at that floor to take on passengers for the same direction. That situation, of course, would be entirely eliminated.

For apartment houses the control is somewhat modified. The elevator runs on a round trip schedule. In other words, of course the complete run up and down takes on passengers and lets off passengers, as the case may be, and no operator or guard is required.

In department stores, for example, particularly where they are stopping at every floor, the guard's only function is to press the closing button for his door and gate and the closing of the door and gate will initiate motion of the car and it goes to the next floor, gets up to the top floor and reverses.

Mr. Reed mentioned that for department stores particularly, 250 feet speed is the accepted and correct limit. I don't quite agree with him. I believe that elevators can be operated satisfactorily and from an economical point advantageously at considerably higher speed. As a matter of fact, even 400 feet speed is probably not the economic limit.

Mr. Reed points out that the average number of stops in office buildings will be from 125 to 175. While that is true, it deserves further consideration. No attention has been paid, to the size of the car. That is a very important consideration, because if you have a large car, carrying a large number of passengers, the number of floor stops naturally will be increased, and if the car is very large, you stop at every floor, or practically so.

I would like to make some statement about the 75 lb. per sq. ft. loading as the accepted standard. While that is an accepted standard for the purpose of rating of elevators' capacities, a baseball crowd, at, for example, 181st Street subway station, pays no attention to the standardized loading of 75 lb. per sq. ft. The average is often over 100 lb. per sq. ft. and, as a matter of fact, we have records of as high as 115 lb. per sq. ft.

This, again, brings out the point that in order to put in adequate elevator equipment, you must know the service conditions.

Suggestion is made to decrease the speed of an elevator for the purpose of economy. Now that economy, in the example, is a false economy. It only deals with economy of power consumption, and not with economy from a broad point of view. Mr. Reed figures out that the interval of time, by using the higher speeds, is only decreased from 17.58 to 16.65 seconds, in other words, less than one second.

Looking into it a little more carefully, you will find that second is quite an important length of time. That difference in interval of time means in approximately twenty elevators you can save one. Now Mr. Reed has figured out that the power saved per year for ten elevators amounts to $288.00, for twenty elevators therefore it would amount to twice that, call it $600 per year. How much do you think that you save per year if you reduce the number of elevators from 20 to 19? Why, you save several times that amount in a building, because the space alone is worth considerably more than the power saved.

The statement is made about the half wrap traction machine that the principal objection is that the traction between the ropes and the driving sheave varies with wear of the driving sheave. That is true with the ordinary V groove sheave, but with a modified construction of sheaved grooving is not true at all. The traction remains with that construction just the same as it does on the U groove.

Now with the wear of the V groove naturally your pressure angle changes, and your traction is decreased. Now, on the other hand, if you want to make a single wrap machine, or half wrap, as Mr. Reed prefers to call it, out of this machine, all you have to do is to undercut your groove and as wear takes place your pressure angle doesn't change, and your traction remains practically constant. Mention is made that it is still an open question whether the full wrap or half wrap machine is the better. It is true, under certain conditions, the double wrap is better than the single wrap or the full wrap is better than the half wrap.

The statement is made that cable life is generally a little longer on the half wrap machine.

There again is one of those general statements that while true, are quite misleading. If you consider the total number of machines in service then it is true but on the other hand the great majority of machines with half wrap consist of geared machines, in which the sheave diameter is considerably larger, for various reasons, than employed with the double wrap, which has principally been used on the gearless traction machines.

One thing, however, is true about the half-wrap, and that is that you have got to be careful in selecting your sheave diameter and the number of ropes and the load per rope, and also the quality of the rope, because the surface pressure between the rope and the sheave is very much higher, and for the same traction effort is more than twice as high as it is with the U groove.

Certain trouble has been experienced due to the fact that this particular situation was overlooked, and in quite a few cases excessive wear of the driving sheaves has been found.

Another statement regarding the slower speed motor for the gearless traction machine. "That inherently means a very large machine." That is true, "and therefore, to keep the size down only a small range of speed is obtained by a change in shunt field." That statement is also true, but I think it is somewhat incomplete. I believe that it might be well to add there that due to the large time constant of a field of a large motor, for the sake of rapidity of acceleration, it it unsuitable to use a large field variation, even if cost was not considered.

In reference to duplex or tandem gear machines, I believe that his statement is somewhat misleading. I refer to this statement: "The field of the tandem-gear elevator is heavy duty continuous service since it minimizes gear pressure by using three points of gear contact." Well, that is true, it has three points of gear contacts but only two of those are in contact with the worm. I made the general statement here that as far as I have been able to find, from my experience with geared machines, there is no advantage at the present time with a tandem-geared machine. As a matter of fact, a single-gear machine with properly designed thrust bearings, is superior to the tandem-geared machine. There may be cases where you, on account of space conditions, require a machine that is built on the style of a Los Angeles bungalow. There, of course, a tandem-gear machine has certain advantages. The tandem-gear really had its days when proper ball bearing thrusts couldn't be obtained.

I don't think that anyone would seriously consider it a cinch automatically to level a 600 ft. elevator by shunt field control or by frequency changing in an a-c. elevator and level that elevator automatically within an eighth of an inch, or say even a quarter of an inch of the landing sill. Still, by reading the author's statement I got that impression.

In regard to counter-weights, attention hasn't been paid to the fact that frequently it is necessary to modify the counterweight on account of lack of traction. Then there is a statement about the benefit of the flywheel effect for smooth operation. Now there again I don't think that anyone would seriously consider adding flywheel effect to an elevator motor for the purpose of obtaining smooth operation. Now I want to call your attention to the fact that the gearless machine, with the best operation, has the least possible flywheel effect. While it is true that flywheel effect may aid a poorly operating controller, I don't think that anyone would put in flywheel effect for that purpose.

I am just going to conclude with reference to rating of elevator motors. The statement that the 15 or 30 minute rating with full load is sufficient to determine whether that elevator motor would not overheat in service. Well, such a test has

absolutely no significance, particularly when it comes to two speed a-c. motors.

H. P. Reed: We will grant, as has been stated in the paper, that the service calculation given, comes far short of covering all cases as it was not the intention of this paper to present details which could only be of interest to those directly connected with the elevator business. A complete treatment of this subject would in itself require a full text book.

The high-speed push-button elevator described by Mr. Lindquist, is very interesting and theoretically ideal, but as those experienced in the art will grant, the more complicated the device is made the more trouble is to be expected. In other words the advantages Mr. Lindquist claims is to increase the elevator service so as to reduce the number of elevators and save building space. However, in the scheme described it is feared that complications have been added which will increase maintenance to such an extent that it will require additional elevators to take care of shut-downs.

In the discussion Mr. Lindquist stated that the paper held 250 ft. per min. as the maximum speed for department store elevators. The average speed, which applies to about 12-ft. floor heights, was given as 250 ft. per min. in the paper, but it will be noted that the paper mentions a speed of 350 ft. per min. as a possible good maximum. This speed would be all right in a building having 15-ft. floor heights.

Mr. Lindquist said he felt the paper could not possibly mean what it evidently conveys, that floor leveling can be accomplished with a shunt field control motor, but as there are many in operation giving accurate results with this arrangement, there is no objection to interpreting the paper in this manner.

Mr. Lindquist touched briefly on heat specifications for elevator motors. This is a very good point and it is hoped that someone in the near future will come forward with a paper giving suggestions of specifications for actual installation heat tests for elevator motors.

J. J. Matson: There are two main points which I wish to discuss in Mr. Reed's paper. The first is the advantages and disadvantages of a high rotor moment of inertia; second, the application of alternating current motors to passenger elevators.

A high rotor moment of inertia increases the power consumption during starting. It also tends to increase the size of brake required. It has often been pointed out that service and smoothness of operation are two of the main features of an elevator installation. This is particuarly true when dealing with passenger installations. Provided a large moment of inertia is used, the smoothness of retardation and acceleration is improved. This is evident on account of the larger amount of stored energy in moving parts. The larger this energy compared to the power being required for moving the elevator the smoother is the starting and stopping.

Mr. Reed has stated that he believes the limit of a-c. motors on passenger elevators to be at approximately 350 ft. per min. I would take exception to this statement, inasmuch as there are several very satisfactory installations at the present time using a car speed of 425 ft. per min. Other installations have been recommended when using a-c. motors to run at 500 ft. per min. This I do not believe is too high a cage speed when using a-c. 2-speed motors.

The higher-speed equipments when using d-c. power supply uses a gearless drive. This consists of a low-speed motor, direct connected, to the driving sheave. A low-speed d-c. motor is a good electrical proposition. When you go, however, to alternating current, there are many inherent difficulties in reducing the synchronous speed so as to use a direct-connected motor. This can be readily understood when it is pointed out that in order to obtain a synchronous speed of 72 rev. per min. it would be necessary to furnish a 100-pole induction motor. Then when you consider that, in order to get slowdown for accurate stops, it would be necessary to cut this speed at least in a third, it is evident that a 300-pole low-speed motor would be desired. For the size of motor involved, this is at the present time practically an impossibility.

We, therefore, can consider that the a-c. installations must be of the geared type, and not only must the motor characteristics be considered, but also the gear characteristics must be considered. At the present time, I believe I am correct in saying that there are few elevator gears in operation at speeds exceeding 500 ft. per min. Undoubtedly, the elevator manufacturers can design and satisfactorily build higher speed gears and still obtain a very satisfactory device. It, therefore, appears that there are two limiting features: first, the gears, which is entirely the elevator manufacturer's problem; second, the motor, which is an electrical problem.

Relative to the electrical design of the motor, it would be possible to install a variable frequency and use this frequency instead of a difference in number of poles, in order to obtain slow downs. This same set could also be used in acceleration with the inherent degrees of power consumption. I believe that the use of a multi-frequency should be considered and investigated, as it certainly appears to be one of the several ways that will enable us to increase elevator speeds when using a-c. equipments.

H. P. Reed: Mr. Matson mentions that the paper gives the limiting speed of a-c. elevators as 350 ft. per min. At the time the paper was under preparation, this was essentially so, but since that time, at least one installation has been made of four elevators traveling regularly at 540 ft. per min. This speed was obtained by the use of motors having a 4-1 speed range.

Mr. Matson's further comments on a-c. motor design limitations will be welcomed by everyone interested in electric elevators.

A statement was made in Mr. Matson's discussion which pointed to the gearless machine as the only type used for the higher car speeds. Exception should be taken to this statement, as there are many geared elevators used on high car speeds.

E. B. Thurston: Reference is made to the downward tendency of elevators speeds. I don't believe it was the intention of the committee or the intention of Mr. Reed to give the impression that seems to be given. Therefore it is advisable to add to that a suggestion that it only applies to a high number of floor stops, because we all know there are installations of 600 ft. per min. where the elevator is stopping at practically every floor, and the higher speed is a very uneconomical installation.

In reference to that statement by Mr. James regarding the rate of acceleration, from our experience on the elevator side we fail to agree with him that the acceleration should be anything but constant. You cannot, it seems to us, change the rate of acceleration without its being objectionable to the passengers riding. There are many installations where this is quite evident. There are probably very few of you in the crowd who have not ridden on elevators which always start out too fast and objectionable.

A standard is mentioned in the paper of 5 ft. per sec. per sec. as quite satisfactory. If you exceed that very much it is objectionable to many people.

Mr. James also made mention of gears getting back lash in operation and stated that he didn't know of any installations where how certain principles had been applied to elevator gears. I would like to state that such principles as he mentioned have already been applied to elevator gears, and are working out very practically. He also questioned the possible rate of acceleration of geared machines. I would like to give him a test made on a geared machine operating at about 630 ft. per min. in regular service. Its rate of acceleration, with 1830 pounds unbalanced load on the car, was just 2¾ sec. It is possible with a geared machine to get and obtain any rate of acceleration, irrespective of the load and it stays put. It is interesting to note, because generally I have been an advocate

of some shunt field control, the results that have been accomplished. With the gearless type of elevator it is not yet possible to build a motor with any appreciable amount of shunt field control. While the gearless machine is a simple mechanical machine, it seems to have sacrificed desirable electrical characteristics, all day operating efficiency, positive speed control, cost of maintenance and constant rate of acceleration, irrespective of direction or load. The results of the last two years of development to get a method of controlling the gearless machine have brought out many new and interesting features. It is interesting to note the use of the multi-voltage, the variable voltage control system, etc., but even with all these added it is still a big question as to whether it is equal to the economic running and cost of maintenance of the straight shunt field control.

H. P. Reed: Mr. Thurston no doubt refers to the statements appearing on page 60, column 1 in the third from the last paragraph. Mr. Thurston's comments are appreciated, as it is agreed that the statement could be much improved upon by adding the facts brought out in the discussion regarding the power economy with higher car speeds under certain service conditions.

It is felt that the statement in the paper is true for elevator service requiring an average of a stop for each elevator at every other floor.

W. S. Atkinson: Many of the larger cities and some states have elevator codes which prescribe with considerable definiteness the provisions that must be made for safety, and these frequently involve major features of design in the installation. For example, while 75 lb. per sq. ft. of floor area is generally accepted standard for determining rated capacity of passenger elevators, as stated in this paper, some codes prescribe 60 lb. for elevators in hospitals. There are also limitations in regard to the application of hand rope and hand wheel control, types of governors and "safeties," etc.

Hence, elevator manufacturers are not always entirely free in selecting equipment but must consult such local authority when it exists.

In the example worked out on pages 59 and 60, January JOURNAL, to determine the number of elevators required to serve a hypothetical New York Office Building, it is noted that the elapsed time from the departure of the car at main lower landings to its next departure therefrom, is designated as "time of round trip." In such calculations the writer prefers to apply this term to the actual time the car is away from the main terminal landing,—the elapsed time from departure of car to its return, which is actually a round trip. The distinction is of practical importance as affording a measure in comparison, excluding as it does the arbitrary allowance for lay-over or waiting time at main landing. The writer used the term in the sense here used in a paper some two years ago outlining this method of developing car schedules, but has abandoned it for the reason stated.

Also the wisdom of serving the sixteen story office building entirely by local elevators, as is here shown as an example, instead of dividing the 10 elevators into the express and local, will be questioned.

The majority of elevator installations going in today outside of the field of the high-speed gearless machine, are alternating current, and the importance of developments in motors and controllers for this application is to be emphasized. The advent of the two-speed squirrel cage motor and a realization that blocks of resistance in the primary could be used as a means of control have marked two important steps in recent successful extensions of the field of a-c. installation, the three-to-one speed ratio being the favorite. A very recent development is the six-to-one speed ratio squirrel cage motor where the low speed winding is made use of in approaching a landing.

H. P. Reed: From Mr. Atkinson's discussion, it is assumed that perhaps the paper includes some statements that are too definite. It was thought that some fairly definite statements should be made in order to bring out discussion. From the number of written discussions received, it appears that the paper has served its purpose in this respect.

Mr. Atkinson takes exception to the method of calculating the number of elevators required for an office building as given on page 60, column 1, in that all variable time factors are not introduced individually. It is felt that these factors carried through as one variable will give just as good results.

It is admitted that the question of whether all local or local with some express service elevators shall be used to serve a 16-story office building is open for discussion.

The same factors as given can be used directly by dividing the elevators up into express and local. In a building of this height however, it is felt that either method may be used with good success. With express and local service for the calculation given in the paper, the frequency of service cannot be less than 24 to 30 seconds, but it is possible to empty the building in a somewhat shorter period than with all cars running local. This condition means that the best elevator service can be obtained by express and local for the outgoing rush hour to empty the building quickly and at all other times all the elevators may be run local and still maintain a floor frequency service of 16 to 20 seconds.

Mr. Atkinson's remarks on the application of a-c. motors to high-speed elevators are most timely. The demand for such equipment is increasing by leaps and bounds, and it is only a question of time when more and more a-c. elevator installations will be made in the down-town districts of our large cities.

Theo. Schou: Gearless traction motors are being built with a speed of 50 rev. per min. with a full field. By weakening the shunt field, this type of motor may be operated at a speed as high as 85 rev. per min. with good commutation. It is believed that by a further study into this type of motor, a special design could be created whereby shunt field speed could be brought down to probably 35 rev. per min., giving a shunt field control from 35 to 100 rev. per min. Though this type of motor has a high running efficiency, the actual operating efficiency is probably lower than the geared machine, due to a rather less amount of shunt field control, necessitating considerable control by armature resistance. If this type of motor, therefore, could be designed with a lower shunt field speed, it would have a higher operating efficiency.

The name plate ratings of elevator motors should indicate starting torque and pull out torque, as well as horse power rating. This would give the elevator builders more definite information in regard to the motor from which to design their installations.

Direct-current motors in most cases have sufficient starting torque when provided with shunt field only; a 10 to 25 per cent compound winding for starting is only necessary for low speed heavy duty service. This compound winding is short-circuited after starting, and it is very difficult to completely short this winding under operating conditions, and therefore, difficult to obtain good speed regulation under varying load conditions.

Direct-current shunt-wound adjustable-speed elevator motors can be built with a speed range of one-to-four and still obtain, by special design, stable speed condition when running at high speed with a weakened field.

Both the single a-c. squirrel cage motors with stator windings for two or three speeds, with speed ratio one to three, or even one to six, and also slip ring squirrel cage elevator sets with a speed range of one to three are being built, and it is believed both these types of a-c. elevator motors have their place and will continue to hold their respective places in the future.

The slip ring squirrel cage motor is built as two motors, and assembled as a 2-bearing set, the low-speed squirrel cage motor being used for dynamic braking when run over speed.

It is true as stated in the paper that the future points to more developments and the supremacy of a-c. elevator motors in comparison with d-c. motors. In the past, there has been a great deal of objection raised to the noise of a-c. apparatus, including the motor, controller and magnetic brake. This

trouble has been eradicated by furnishing motor driven control in place of the noisy magnetic control, and this has inspired motor builders to do all possible to remove the noise from their motors so that the a-c. equipment of modern type can now be procured for very quiet operation, and is controlled much better today than in the past.

H. P. Reed: Mr. Schou suggests a wider range of speed control by shunt field regulation for d-c. gearless traction elevator motors. This is a good suggestion, as a design of this nature will give the advantage of greater power economy, as well as more positive low speeds under different loading conditions. However, it is believed that Mr. Schou's suggestion of a maximum speed of 100 rev. per min. or even 85 rev. per min. is not practicable for a gearless machine with one-to-one roping as this would mean car speeds greater than allowed by law at the present time as it is considered that the approximate minimum diameter of driving sheave is 30 inches.

Arthur Liebenberg: The most significant statements in the paper seem to the writer to be

(1) That elevators of the worm gear type are now produced, giving perfect service at any speed up to 600 ft. per min.

(2) That the safety and economy of these types now seems to be superior to the gearless.

(3) That excessively high car speed is expensive and does not necessarily accelerate the traffic.

The writer would like to give a few added details of how and why this is true.

The tardiness of the worm geared elevators in claiming a place in the highest class of service has been due to the failure to perfect its details rather than any inherent fault of the type. The reverse is true of the type, for it was evident to the first inventor that the shunt motor had all the safety and other features needed but that some gearing was necessary to combine a commercially possible motor of 800 revolutions with a practically possible car speed requiring a 60 revolution drum. Nothing seemed more obvious than a worm gear and therefore it was the first used, and has been used for the lower speeds ever since. Only recently, however, designs and machinery have been perfected for producing commercially a satisfactory worm and gear. Today they can be produced, hobbed if you please, so they will run perfectly without any grinding in. The surfaces in contact are sufficient to give proper oil flotation so wear will not show in years of service.

The second factor that made the worm geared elevator for high speeds not only possible but most logical was the development of the interpole shunt motor.

The interpoles fix the point of commutation so that definite speeds can be obtained with variable loads by means of shunt field regulation.

The speed range for elevators having variable, positive and negative loads may be as much as 3½ to one.

All these speeds can be fixed within 3 per cent regardless of the load. Sparking or flashing on the commutator is avoided and heating need not be considered.

The motors are wound plain shunt except for the series turns on the interpoles. Some current is maintained in the field to give fast acceleration. For elevator work such a motor is ideal where direct current is available. For alternating-current, two-speed motors have now been developed having similar characteristics to the d-c. shunt motor. These also require gearing to keep the motor within commercial limits.

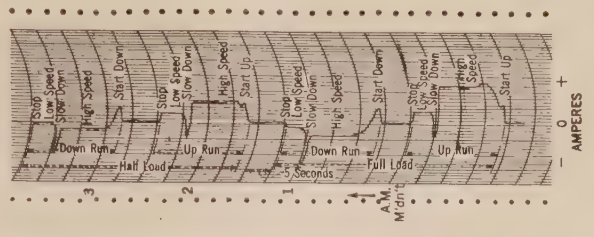
The interpole motor is desirable for elevator use because,

(1) In its economical speed range it is inherently safe from runaways for a wide range of loads.

(2) It has so much excess capacity at low speed that it can be given as fast acceleration as may be desired.

(3) The fixed low speed permits most accurate floor stops to be made. These stops are so definite that they can be made automatic if desired.

(4) The control is simple consisting of line and reverse switches and resistors in armature and field. The surplus power eliminates all questions of safety, leaving the problem of acceleration simple. With automatic and uniform timing of control steps the car accelerates in equal times regardless of the load.



220 volts. Each division 10 amperes. Read right to left.

Fig. 1—Graphic Ammeter Record of Test

Elevator capacity 3000 lbs. at 400 ft. per min.
Motor........................220 volts, 120 amperes
Full load starting current.................. 60 amperes
Full load accelerating current...............130 amperes
Full load running current...................120 amperes
Full load running efficiency.........................70%
Power consumption between 2½ and 3 kw-hr. per cm. mils for office building service.

It is economical because armature resistance, which is used only in accelerating up to the slow speed is all cut out when the car has traveled 12 inches. The field regulation used in accelerating above the low speed entails practically no loss. Dynamic braking regenerates the energy of starting and restores it to the line as useful current. See graphic ammeter curves in Fig. 1. The running efficiency is so near that of the gearless that these savings make its average efficiency much greater in any service where the loads are variable and the stops frequent.

Variations in speed in a standard shunt motor without interpoles amount to 15 per cent either from balanced load to positive or negative full load. Hence in a gearless equipment even with multiple voltage control the low speed for stopping will probably vary that much with differences of load. Hence while these expensive luxuries will improve the efficiency they leave the problem of making accurate stops to the second extravagance, the levelling device.

With the fixed low speed of the interpole worm gear elevator the power can be cut off at a point within about 8 in. of the floor and an accurate landing assured. The stop is attained with a combination of dynamic and two shoe brakes, one on the worm and the other on the drum itself. The drum brake prevents the slap from back lash that would occur when the direction of pull is reversed on the worm.

This brake has long been applied to the tandem worm gear but only recently to the single gear type.

Worm gearing is much more efficient than usually thought, not less than 95 per cent in the average passenger elevator units having 9 to 18 revolutions of the worm to one of the drum.

It is dependable and durable, showing little wear in 20 years of hard service. Ball or roller bearings are used to take the annular and thrust loads of the worm. The other bearings are provided with bushings of babbitt metal that are interchangeable.

Drum type traction, which the author did not describe, consists of a single chased drum on which the six ⅝ in. cables used are laid together, giving each one and one-half wraps of contact. When the elevator moves these cables travel together, along the face of the drum, a distance of a single groove for each revolution. This amounts to about 10 in. for 150-ft. run of the car. The standard idler traction described in the paper gets 2 half wraps so that slipping is usually imminent and the cables cannot be lubricated as they should. Further than this the idler triples the number of bends in the cables and the friction of the drum shaft and its idler. With the drum type of traction there is no

slipping, and creepage due to differences of the average load is limited by a switch in the drum.

Readjustments of the cables is accomplished quite easily by running the car or weight on the buffers, relieving the traction.

Seven years of experience assured us that this system of traction is entirely safe and satisfactory.

Timing and the control of resistors with small motors through cams, one for the armature resistor and one for the shunt, has prove very satisfactory. It is very quiet in operation and lends itself to the proper adjustment of the acceleration to get the fastest comfortable rate.

Control is a prime requisite for good elevator service and the confidence born of smooth acceleration and accurate stops greatly accelerates the movements of the passengers entering and leaving the car.

The Warner Elevator Company has contributed largely to the development of the single worm gear elevator, which it has built exclusively since 1895. In 1915 it developed the ideal type described herein, which it has produced in large numbers ever since. It has given such good and economical service in high buildings that the makers of the gearless types have had to resort to multiple voltage control for groups of elevators and variable-voltage Ward-Leonard control for single units to meet this competition. There seems to be no warrant for the gearless equipment in buildings of less than 20 stories and not in them for local service.

W. H. Patterson: The variable voltage control system is an old principle and one thing that hasn't been spoken of very much here this morning was the noise and burning of contacts, on the control boards, which means cost of upkeep. That is one of the principal advantages in this system of control. We don't open any heavy armature currents, such as 150 or 200 amperes, but are merely handling field currents of three to five amperes.

Mr. James gave you a brief description of this system, so I will not repeat. But I would like to point out to you the current consumption that we recently got in tests which were made, on some elevators traveling 12 floors, with 2000 lb. load, at 500 ft. per min. With the balanced load and 75 stops per car mile, we got 1¾ kw.; with 150 stops we got 2¼ kw.; with 300 stops, 3 kw. With full load in the car and 75 stops per car mile we got 2¾ kw.; with 150 stops, 3½ kw., and with 300 stops, 4.7 kw. These tests show a remarkably low kilowatt consumption per car mile. They were made by our engineers and were recently checked by Mr. Bassett Jones of New York. He got practically the same results to the third decimal point. I therefore believe that this system of control warrants the attention of all elevator engineers and manufacturers. It offers the advantage, first, of smooth acceleration and deceleration; second, of low-current consumption; and third, low maintenance. The maintenance cost on your control board is going to be practically negligible because of the small current you are handling. Fourth, it solves the problem with a-c. current for high speed elevators. While great progress has been made in the last few years with two-speed motors, I think there is considerable developmental work yet to be done along that line to have it as satisfactory for high-speed passenger elevators as is the system of control such as this.

H. P. Reed: Mr. Patterson's discussion on the variable voltage elevator control is very interesting. It is felt however, that the power consumption tests do not tell the whole story on power economy. Test runs may easily be made with this system of control and show a considerable economy. However, it would be interesting to know just what the all day test will show, for instance, for an office building where there are not many stops per car mile, where the elevators are in service at least running not over 30 or 35 per cent of the time and where the standby losses of the generating equipment constitute quite an item in the power bill.

Bassett Jones: For the reason that not even an approach has been made toward a solution of the service problem in freight elevator engineering, I shall confine this discussion of Mr. Reed's paper to passenger elevator engineering. The passenger problem is relatively simple because, as has been said, "the passenger is a standard automotive package that stacks itself in one tier." However, this is only approximately true since the package in question has ideas of its own. But, being human, he does, in general, as all other passengers of his own class do, and so permits himself to be averaged as a member of a package group. Therefore there is some reasonable basis for treating the passenger as such a standard package.

As Mr. Reed says, service requirements form the premises from which the character, arrangement and size of the elevator equipment should be deduced. This point should be heavily accented. The determination of service requirements is the only logical basis for the solution of any elevator problem, freight or passenger. Given the service requirements, a determination of the most suitable size, duty, number, and arrangement of cars follows by mere arithmetic. But no amount of arithmetic will give the right answer unless the premises are sound. An error in determining the probable elevator service requirements in a building leads to a wrong determination of equipment no matter if the subsequent calculations be most precise.

Unfortunately the determination of service requirements must remain largely a matter of judgment based upon experience, and upon statistics gathered by painstaking observations. At best the answer is an intelligent guess, and so we have recourse to the best possible method of guessing—probabilities and frequency graphs.

Such studies in elevator services show that there are several important service factors, or rather coefficients, the probable value of each of which must be determined in each case before the probable service requirements as a whole can be properly established.

It is not merely a question as to how many people must be handled in a given time, but also what kind of people they are. Their working habits and group psychology must be determined. How promptly do they come to work, or leave, or go to lunch? How long can they be expected to wait in the corridors for a car without complaining?

All these and many others have to do with geographical location, vicinity to transit terminals, class and business methods of tenacity, etc. In these respects a bank building in Boston is not the same as a bank building in New York. Nor is an office building in down town New York the same as an office building in up town New York. Then, in office buildings alone, are the tenants, bankers and brokers with the attendant stream of messengers; are they professional; are they in insurance or in the textile trade? Are the tenants permitted to do small manufacturing such as clothing; will they in general occupy large areas with employees on the time clock, or will they occupy small areas and have few casual employees? These are a few of the questions that must be answered.

The renting management must also be considered. Today, many buildings are inadequately elevatored, but had they been rented differently, would have ample elevator facilities. A single large tenant occupying separated floors may entirely upset the assumed desirable schedule. In general, the larger the individual tenants the worse the conditions will be.

In addition the tendency of real estate development must be studied, also in a few years the building may prove to be hopelessly under elevatored, or, on the other hand, it may be stranded with a costly equipment on its owner's hands. The space of ten years has seen radical changes in the character of certain districts in our larger cities.

Having come to this point in our study, the next question relates to the probable total population that must be handled, either initially or ultimately. This will vary widely with the

factors noted above. Depending upon these the population density may be anywhere from 40 sq. ft. rentable area per person to 200 sq. ft. rentable area per person.

The next step is to establish the probable rate of traffic flow, separately for the arrival period, for the departure period, lunch period, inter-floor traffic, and transient traffic. These, too, will depend on the locality, class, and working factors above enumerated. The arrival traffic may be anywhere between 20 per cent of the population in 15 minutes and 50 per cent of the population in the same time. The arrival traffic may be denser than the departure traffic or vice versa, and the departure traffic is more difficult to handle because of the absence of starters where it originates. Or, again, the combined inter-floor and transient traffic may be the determining factor in establishing service requirements. The location of toilets, restaurants, clubs, locker rooms—all must be considered as elements in the problem, and sometimes very important elements.

Thus, for example, measurements have shown that on the average, every woman in an office building visits the toilet, or woman's rest room, once an hour. Since 15 per cent of the population may be women, this means that 15 per cent of the population uses the elevators twice an hour, or 7.5 per cent in 15 minutes. Obviously the location of women's toilets has considerable bearing on our problem. Suppose the combined arrival and departure transient traffic is 8 per cent of the population in 15 minutes while the simultaneous business interflow traffic is 10 per cent of the population influx during 15 minutes. The net result including the female traffic is that over 20 per cent of the population use the elevators in 15 minutes, and this, due to the greater number of stops required, may be a heavier demand on the elevators than $33^1/_3$ per cent of the population arriving in 15 minutes during the morning arrival period. The 15 minute interval is frequently used as a convenient standard time measure. It is quite arbitary however.

Next we must know something of the probable distribution of the traffic flow during the worst period. What is its peak value and for how long does it last? Suppose that the average maximum arrival traffic during the 15 minutes is 25 per cent of population in this time. That is, during the worst 15 minutes 25 per cent of the population arrive at the building. During five minutes in this 15 minute period, the average rate may be 25 per cent greater than the 15 minute average, and allowance for this must be made unless crowding and delayed service is to result. Commonly, variations in traffic flow are observed by counting passengers entering the cars every five minutes. Graphs of such observations continued all day usually furnish a curious, and sometimes amusing commentary on the habits of the tenants. The character of the traffic frequency distribution will depend on the tenancy character factors previously mentioned.

I have devoted so much time to this sketch of service factors, because, after all, they constitute the basic data for our calculations. Without such a determination of traffic flow any method of determining the physical character of the elevator equipment results, as it begins, in a pure guess.

Questions as to corridor dimensions and arrangements as well as the size and types of door ways giving access to the corridors have not been mentioned above. As affecting the flow of traffic to and from the cars, such matters are of importance and should be studied.

Having covered these preliminary subjects, we are now in a position to discuss briefly the logical sequence of steps in the subsequent calculations.

We have established the probable traffic flow at the cars for arrival and departure periods, as well as the inter-floor and transient traffic and have selected one of these as determing the maximum service conditions. This selection may not be quite so obvious. In which case the computation will be made for the arrival traffic and then, as a matter of comparison, for the inter-floor and transient traffic.

Generally the computation will be started by assuming a desirable interval between cars. This, for the reason that the satisfactoriness of the service is determined by the interval or, what is the same thing, the maximum time a passenger has to wait for a car. On the average the car stands the full interval at the ground floor. This will vary with conditions of traffic. On the average a car travelling in each direction of motion passes each landing every interval. A car leaves the top landing every interval. Note that the interval taken is an average—it may be longer or shorter. If the interval, as an average, be taken too long in the beginning the maximum interval during the worst conditions may be out of all reason. Cases are on record where bad car design and restricted openings have increased the interval during a crowded period of inter-floor traffic to 4.5 minutes in a 16-story building. During the inter-floor period the traffic is equal in both directions, passengers both get on and off the cars at the same stop, and a crowded car, may and generally will, cause a considerable increase in the round trip time, lowering the interval. Frequently. it is necessary to accept an inter-floor interval longer than the arrival interval.

Waiting for a car to arrive, or standing in a car that is not in motion, is the feature of the service that makes it seem either sluggish and slow, or snappy. Under these conditions 30 seconds seems 30 minutes to the impatient business man. It is entirely a question of passenger psychology, but it indirectly affects the rental value of a building.

In the highest grade office buildings in the New York financial district arrival intervals as short as 20 seconds have been used, but due to increasing population this is rarely maintained. A 24-second interval is considered good service; a 30-second interval is only fair service; a 40-second interval is slow service. The desirable intervals vary in different cities. In Boston, for instance, a 30-second interval is quite satisfactory.

Assuming a given interval as a starting place, from it must be deducted the time required to open and close car gates and landing doors at the ground floor to find the time available for handling passengers. For power operated gates and doors this deduction may be taken as 3.0 seconds. For hand operated gates and doors without car-landing door interlocks the deduction may be taken as 5.0 seconds, and with such interlocks 6.0 seconds or 7.0 seconds. The remaining time is available for unloading and loading passengers.

At the ground floor, where a starter is in charge, passengers can unload and load in 1.0 second each. At other floors the time per passenger will average 1.25 seconds with wide car openings, uncrowded cars and a reasonably effective means for announcing the arrival of the car at the landings. With crowded cars or restricted openings the time will increase. It is also increased in deep narrow cars. In crowded deep narrow cars the time may rise to an average of 2.0 seconds per passenger, and seriously affect the service.

Let us now assume a case. Assume arrival traffic amounting to 1000 persons in 15 minutes, and a 5-minute maximum of 416 persons. Assume a 30-second interval as desirable; hand operated gates and doors. Then the maximum number of passengers that can be loaded in the remaining 25 seconds is about 25. To prevent crowding a 30 passenger car should be used. But this is a very large car, and in office building service will run lightly loaded most of the day with marked unbalance and therefore at high average power consumption. Our traffic studies for this building show that the average load for the day will be 4 passengers, which, with the operator added, is a load of 750 pounds, and should be as nearly equal to the difference in weight between car and counterweight as it is reasonably possible to make it.

Let us then assume a 20-passenger car and either instruct the starter that only in emergency is he to admit more than 16 passengers, say during the 5-minute peak, or, cut down the interval to 25 seconds, which, as a matter of fact, is the best alternate, for then only 20 passengers can enter in the time available.

It is assumed that during the arrival period no passengers

will be unloading since none will be coming down from the upper floors.

Let us then correct the interval to 25 seconds. Then in 5 minutes 12 cars leave the first or ground floor each carrying 20 passengers—a total of 240 passengers. But in this time during the peak 416 passengers arrive. Obviously the remaining 176 passengers must be carried in another bank of cars.

This second bank could have smaller cars than the first bank, but, due to possible shifting of population density in the building, it will be wiser to make all cars of the same size. The area of the car platforms should be 42 sq. ft. arranged 7 ft. wide by 6 ft. deep. The maximum load rating will be 3150 lb.

These cars, two wide in a bay, will require a double hoistway, about 16 ft., 4 in. wide by 7 ft. 10 in. deep clear inside dimensions. Unless service conditions demand that the steel work be designed to permit this, generally hoistways of such dimensions can not be obtained. This is one of the unfortunate factors in elevator engineering. Architects rarely consider the real importance of installing cars of the right size, compelling the use of a larger number of smaller sized cars at a greater first cost and operating expense. In the above case, it may be necessary to use cars 6 ft. wide, then a depth greater than 5 ft. 6 in. is wasted. The platform area is 33 sq. ft., the rated load 2500 lb. The maximum passenger capacity is 16 persons. The interval becomes 21 seconds if delays and waiting at the ground floor are to be avoided. There are 14.3 departures in 5 minutes, giving 228.8 passengers maximum per bank. The service is almost the same as with the larger cars at a longer interval as it should be, but more cars, or more expensive elevators of higher speeds and acceleration will be required to maintain the shorter interval. Thus the building structure itself also effects the situation. Let us, however, suppose that the larger cars at a 25-second interval can be used. We have now established the size of the cars, their maximum duty load and the number of banks.

To determine the number of cars in each bank we must calculate the average round-trip time in each bank. This, divided by the interval gives the number of cars, required in each bank. The calculations are given in extenso to show how and where the different variables enter in and affect the result.

For purposes of calculation the *round-trip time* may be conveniently divided into *running time*, or the total time the car is in motion, the *standing time*, or the time the car is at rest during its round trip, and *lost time*, or the time consumed in false stops, limit stops, synchronizing, etc.

The running time is best determined from time-speed data for the various types of hoisting engines. The best type to use is the one that makes the running time a suitable proportion of the round-trip time. This establishes the desirable velocity—acceleration characteristic of the equipment.

The *standing time* is made up of time consumed in operating gates and doors and loading and unloading passengers, at all stops above the first floor. To this is to be added the interval, or the time the car is standing at the ground floor.

Let us start out by taking the first bank. Let the building be 20 stories. The proportion of the population to be handled by the two banks is as 176/240 = 0.73, assuming equal population on all floors which may not be true. Then the first bank will feed 0.73 × 20 = 15.6, call it 16 floors. The hoist is 207.5 ft. on the average. The cars will stop at 0.8 of the landings "up" motion and none down motion. Therefore they stop at 0.8 × 16 = 10.8 landings, and the average "jump" or distance between start and stop is 207.5/10.8 = 19.2 ft.

On the way down the car makes one jump of 207.5 ft.

On the way up the car starts with full load and ends with no load, so its average load is half full load. On the way down it is lightly loaded. Therefore, it will travel faster on the way up than on the way down when maximum unfavorable unbalance exists. These differences may amount to a material item in computing round trip time.

The standing time is made up as follows:

Gates and doors, 10.8 stops at 5 sec.	=	54.0 sec.
Passengers, 20.0 × 1.25 sec.	=	25.0 sec.
Interval		25.0 sec.
Total		104.0

The time lost is—

One limit slow down at top	=	3.0 sec.
25 per cent false stops at 2.0 sec. = 0.25 × 10.8 × 2		5.4 sec.
Synchronizing		5.0
Total		13.4

The sum of the standing item and the lost time is 117.4 sec.

Let us try 8 cars in the bank, then if R be the running time, we have

$$E = \frac{R \times 117.4}{25}$$

or

$$R = 82.6 \text{ sec.}$$

Assume a car on resistance control running at 600 ft. per min. 5.0 second acceleration time rated at balanced load. The time-speed curves for such a 1:1 roping direct drive hoisting equipment show that running down light it will accelerate just to maximum velocity and at once retard to a stop in 9. 5 seconds, and will cover 60 ft. in doing it. The remaining travel at maximum velocity is 207.5 − 60 = 147.5 ft. which will be covered in 14.7 seconds.

This leaves 82.6 − 14.7 = 67.9 seconds running time up motion or 67.9/10.8 = 6.3 (nearly) seconds per jump of 19.2 feet with half load in the car. The time-speed data for this equipment show that the car will do this actually in just under 4 seconds. So there is a small amount of time to spare.

If power operation of gates and doors were used, 10.8 × 2 = 21.6 seconds would be saved. This, added to the spare running time of 2.3 × 10.8 = 24.8 seconds is practically two intervals, so two cars can be saved in this way, and the bank reduced to six cars. Without power operation of gates and doors, one car may be saved, making the bank seven cars. *Every time an interval is saved, a car is saved.* Obviously, the method outlined is subject to many variations. We might have started the calculation of the running time by assuming a velocity and speed and a type of hoisting engine, instead of assuming a number of cars. Then the running time would be calculated from the time-speed curves of the equipment assumed, next, the round trip time determined, and finally, the required number of cars obtained. The method is necessarily cut and try because there are inherently more variables than equations in the problem. It has the advantage over the method proposed by Mr. Reed that the variables are all put in one place where they are recognized as such, and can be given experimental values until the best solution is reached. Empirical formulas and methods are largely eliminated.

In one recent case I completed over 60 separate calculations before the best possible answer was found. But the resulting saving in first cost between the poorest and the best was in six figures, and the annual savings were in five figures. Of course, this was a very large installation in five banks of cars.

There are one or two other points in Mr. Reed's paper that I want to discuss very briefly.

The height of buildings are decidedly limited by the elevators—Mr. Reed says they are not so effected. If cost of space occupied by the elevators is considered, as well as building costs, it can be shown that in high grade office buildings on costly plots where taxes are high, it is not possible to economically elevator buildings above 26 stories in height in the usual manner unless the service to the upper floors be curtailed. When zoning laws affect the situation the 20th floor becomes the economic limit. The only recourse is to much higher velocity than the law now

permits and to extreme acceleration. In order to make it economically possible to build a building 36 stories high in New York under the zoning law, it was found necessary to use cars reaching a velocity of 800 to 900 feet a minute in 3.0 seconds, requiring automatic voltage control and push button initiation of starts and stops otherwise entirely automatic. The owner desired a taller building so as to get more space, but is proved entirely uneconomical.

Unless the entire character of real estate development alters, such buildings are the future type, and, in them, elevators must attain velocities now unheard of. New types of control and operating devices will be necessary, and are, in fact just beginning to come into use. The additional cost of the elevator unit is little if the number required to furnish service can be reduced sufficiently. Nor does the increased power consumption at these velocities amount to a serious factor, for the saving of a few feet of rentable area can easily offset it. In fact, it is the overall cost that counts, and the power costs are but a minute fraction of the whole. Relatively speaking, reduced elevator speeds may save a penny here and there, but to offset this they reduce the whole rental value of the building, besides requiring more cars and consuming more rentable area. As a matter of fact, multi-voltage control may save as much as 30 per cent of the kilowatt hours required to give the same service with resistance control, yet this saving may be but a few per cent of the total consumption by the building and at a very low rate. The main value of such controls is not in saving kilowatt hours, but in making it possible to attain rapid acceleration, just as the principle value of the auto-leveler in passenger service is to make stops possible at high velocities. In general, both of these devices are essential for economic elevatoring of buildings 20 floors high or more. Where the stops are frequent, they may be worth while in buildings not so tall.

Mr. Reed suggests that a downward revision in car velocity is of advantage to the owner due to the lower power consumption of the low speed car. In my opinion this is an entirely fallacious argument. The reasons for this opinion may be best set forth by a specific case.

A particular office building in New York has 28 floors. Up to and including the sixteenth floor a proper service can be obtained with cars traveling at 600 ft. per min., attained in 5 seconds—the maximum conditions giving good operation and reasonable freedom from false stops with resistance control and car switch operation. With voltage control the same smoothness of operation and percentage of false stops can be obtained at 700 ft. per min. attained in 3.0 sec. The resulting average increase in service capacity is figured from the time-speed curves at 12 per cent. Therefore, in the total of 17 cars, as computed on the 600-ft. 5-sec. basis, 2 cars are saved, resulting in a net first cost saving of nearly $20,000. The kilowatt-hours are cut 25 per cent amounting to $2400 a year. Two operators are saved amounting to $3000 a year. Interest and amortization are reduced by $2400 a year. Maintenance is reduced by 5 per cent or $500 a year. Grade B rentable area amounting to 2500 sq. ft. is saved, which at $3.00 rental value is $7500 a year. The total yearly saving is $15,300. Of course, all figures are approximately to 10 per cent variation.

Above the sixteenth floor, a bank of 8 cars rated at 600 ft. 5.0 sec. is required. Changing to rating to 800 feet—3.0 sec. voltage control, auto-levelers to make stops possible under these conditions, and incidentally eliminating all false stops, with power operation of doors and gates, push-button car operation and grouped landing signals, reduces the bank to 6 cars. The saving in first cost is not material but there is a saving of 1900 sq. ft. Grade A rentable area at $5.00 a sq. ft. or a yearly saving of $9500. In addition the kilowatt-hours are cut 30 per cent and two operators eliminated. But the principal factor is the saving of rentable area amounting to 5 per cent of that total which determines the economic possibility of the building above the 20th floor. Numerous other similar cases might be cited.

In all of this I wish to draw your attention ot the necessity of determining running time from time-speed curves obtained by accurate methods such as by the oscillograph, and to the fact that empirical methods of estimating elapsed time between start and stop may introduce serious errors in computing the round-trip time. The obvious errors in the methods of estimating time by the scheme of calculation given by Mr. Reed must be eliminated. A large amount of data both of running time and standing time must be accumulated and reduced to frequency tables by which the coefficients may be intelligently classified. It will then be found that the average deviation from the mean can be reduced to a determinable probable value.

There is no present reason why velocities as high as 1000 ft. per min. should not be used. The only limit is the physiological effect on the passenger, not due to acceleration or to retardation, but due to rate of change in air pressure. Discomfort due to rapid acceleration can be eliminated by voltage speed control of the motors. The disagreeable effect so common with resistance speed control even at velocities as low as 650 ft. per min. attained in 5.0 seconds, is entirely due to the rate of change of acceleration being a variable. There is no discomfort when traveling at a constant velocity of any amount except that due to change in air pressure. The discomfort appears only when the velocity changes, and then, only if its rate of change be irregular, or perhaps if the acceleration or retardation be so excessive that the equivalent variation of the gravitational field increases the weight of the body to a point approaching the elastic limit of the muscles.

One other matter—the a-c. elevator. This is a matter of vital importance to the public utilities companies in our bigger cities. At the present time the velocities attainable are limited due to the inherent character of the a-c. motor, and not inherently in the control, as Mr. Reed states. It is a high speed motor and must drive the drum or sheave of the hoisting engines through a mechanical gear. High velocities via a gear of any ordinary kind are doubtful, although the writer is responsible for one such installation operating satisfactorily and economically with a car velocity of 400 ft. per min. I think it could be jacked up to 500 ft. per min. The motor used is a double affair—a two-speed squirrel cage and a slip ring on one shaft, the two stators in one housing. But at the higher velocities, d-c. direct drive hoisting engines on proper voltage control can be operated from an a-c./d-c. motor generator set at less over-all power consumption than required by the d-c. hoisting engine on resistance control—in many cases this saving will be sufficient to pay for the added cost of the voltage control, particularly where the change to a-c. service brings about a reduction in rates.

H. P. Reed: Mr. Jones mentions that no solution is given of the service problem on freight elevators. The service problem on freight elevators is so varied that it requires a special solution in each case, depending on the use of the building and the method of handling material.

Mr. Jones goes into some details on the service problem which is felt are not of particular interest to the electrical engineer. We must take exception to his maximum population density of 40 sq. ft. per person. This means but approximately 6 x 6 feet of space per person, which is felt is almost impossible inasmuch as rentable areas is understood to include closets, safes, partitions and all lost space outside of corridors.

Mr. Jones takes exception to the method of calculating the number of elevators required for an office building and favors the introduction of each variable factor, whereas it is felt that these factors carried through as one variable will give just as good results.

In the discussion, a criticism was made of a statement that height of buildings are not limited by the elevators. In making this statement it was not intended to include commercially eco-

nomical construction of any particular building due to the size of the plat or the shape of the building. As far as the mechanical and electrical features of the elevator are concerned, they can be built for any height of building.

Mr. Jones' criticism of the suggested saving due to slower speeds was answered by Mr. E. B. Thurston's discussion.

The discussion mentioned that a 30 per cent power saving can be realized by applying multi-voltage control in place of rheostatic control. This may be so for the elevator machine as a unit, but it is felt that the stand-by losses of the generating equipment producing the various voltages will off-set to a large extent any possible power saving.

Mr. Jones mentions the advantage of the auto-leveler in passenger service in order to make reasonable stops at high velocities. While this may be true in some types of motors and control, it is not true of some other types. The use of shunt-wound d-c. motors with a wide range in speed control by shunt field regulation and a constant time element acceleration control provides an equipment which will give accurate slow speeds and practically constant rate of acceleration, regardless of load conditions. Therefore, with equipment of this nature, accurate stops can be quickly made without the aid of the auto leveler.

According to Mr. Jones the paper mentions that the limitation of speed of elevators driven by a-c. motors is due to inherent control limitations. We fail to see where this statement appears. No such limitation exists as successful installations of passenger elevators driven by a-c. motors are now operating 540 ft. per min.

It is granted at high velocities with an *ordinary* gear, but as stated previously in the paper, it is being proved daily that if correctly designed and constructed a geared elevator is giving as smooth and satisfactory operation as any gearless type, and with greater economy. Moreover, as the multi-speed a-c. motor can be successfully applied to the higher elevator car speeds, there is no need for the transforming to direct current with the resultant stand-by losses.

H. L. Wallau: In all of our larger cities we have the d-c. system of distribution in what is generally known as the down-town or business area. This development came about very naturally, due to the fact that the Edison System was the first developed and the cities that are now the largest cities, were the largest then, and had the initial electric systems installed. However, there are a great many of the medium sized and smaller cities in which the Edison system is not in use, and a-c. current only is available, or in certain cases special 500-volt d-c. elevator circuits are run.

Now these smaller cities are gradually getting into the class of the larger cities, larger buildings are being erected, so that they are becoming metropolitan in character and high-speed elevator service is required. It is therefore very gratifying to note that an installation is being made in Toledo today in which three hydraulic elevators are being replaced by a-c. elevators with a speed I understand of 550 ft. per min. I have been told, although I haven't personally inspected the elevators, that their operation is very satisfactory, quiet, the acceleration is smooth and the development begins to have very hopeful possibilities.

Mr. Hellmund: It occurred to me in this discussion that there was too much reference made to the speed of the elevator when a-c. and d-c. service is compared. It is not so much the speed of the elevator that limits the application of the a-c. motors as it is the number of stops that are made. The two-speed squirrel-cage motor, which is now applied to some extent to elevators, will give excellent service if the number of stops is not too frequent. As is well-known, all the starting energy and the braking energy, from the high speeds to low speed, is dissipated in the motor, and therefore the number of starts and stops is of utmost importance with regard to the motor heating.

In this connection I should like to refer to one point in the paper where certain calculations are given about the loading of the motor. With a squirrel-cage motor, it is not only a question of what the load is, but it is also very important to consider how often it has to start. If one goes too far with the frequency of starting, overheating will result even with zero load. For this reason, I believe that the two-speed a-c. elevator motor, while undoubtedly having a large field of application, cannot be applied to everything. When it comes to frequent starts, something else has to be used.

One possibility for such cases is the two-speed motor with wound secondary, which is, however, not a very elegant solution of the problem on account of the many slip rings and the complicated control.

Another possibility, previously mentioned, is the Ward-Leonard system of control changing from a-c. to d-c. power. This certainly has a number of attractive features and, for the higher class of elevator with frequent starts, it looks like an excellent proposition.

Reference has also been made to the possibility of obtaining adjustable speeds for a-c. motors by means of frequency changers. The Westinghouse Electric and Manufacturing Company has an installation in operation where frequency changers have been applied with good success. Of course, this requires an extra piece of rotating apparatus, and if such is used, it is perhaps just as well to convert to direct current and have the additional advantage of being able to use the direct traction arrangement, which is almost impossible with a-c. motors.

Another point which has been briefly mentioned in the discussion is the question of noise. One of the speakers stated that a-c. motors can now be built so that they are not so noisy. That is somewhat optimistic. In connection with the noise problem, we must realize that it is largely a question of natural periods and resonance of various parts, and no engineer is able to calculate the natural periods of the various parts entering into an elevator installation. Motors may be quiet in one place or one position, and when they are put into the pent-house, they may vibrate on account of the resonance effect of the floor. Therefore, we cannot claim that the noise problem is fully solved. But there are certain predominant causes for noise, which are now more fully understood than in the past, and therefore the matter is not altogether hopeless. I think we shall be able to equip the large majority of a-c. elevators pretty soon so that they can be called practically noiseless or, at least, not any noisier than the d-c. installations.

H. P. Reed: The author hopes that the paper with discussions will be of value to architects, engineers and to everyone connected with the manufacture and use of electric elevators. Perhaps more real active engineering problems are occupying the attention of the elevator engineers today than at anytime in the history of the elevator business. Many of these problems are but briefly mentioned in the paper, but are deserving of further study. It is hoped that further elevator papers will soon be available, particularly on the following subjects.

(1) High-speed elevator travel using a-c. motors.
(2) Variable voltage control (Ward-Leonard system.)
(3) Automatic leveling devices.
(4) Multi-voltage control.
(5) Door interlocking equipment.
(6) High-speed push button and dual control.
(7) Actual comparative test results of power consumption for the many types of machines, motors and control.

Transmission Line Relay Protection--II

BY E. A. HESTER
Associate, A. I. E. E.
Brooklyn Edison Company, Brooklyn, N. Y.

R. N. CONWELL
Associate, A. I. E. E.
Public Service Electric Company, Newark, N. J.

O. C. TRAVER
Member, A. I. E. E.
General Electric Company, Schenectady

L. N. CRICHTON
Member, A. I. E. E.
Westinghouse Electric & Mfg. Company, Pittsburgh, Pa.

Review of the Subject.*—This paper is divided into three parts, the first part consisting of a list of relay nomenclature according to function and application, the second part being a general discussion on relay protection with special reference to an investigation of the Protective Devices Committee to obtain information on transmission line protective scheme and the third part, an illustrated description of the results of the investigation.*

The thoroughly proved methods have been given scant consideration but the operating results of new schemes have been treated in brief detail with a statement of the condition which led to the adoption of the various schemes. Many of these schemes require the use of special apparatus which is not obtainable in the open market, though in most cases it was possible to use standard apparatus. It is quite probable that some of these special schemes will be adopted by the leading manufacturers with more or less modification.

In the majority of the cases cited, the actual operating results showing the number of correct and incorrect relay operations have been given and it is probable that this is the first time that such a disclosure has been so generously and frankly made.

Standard names for relays as to function and application as well as qualifying terms which always have the same meaning are very desirable. The number of types of relays now in common use are so great that considerable confusion has resulted from a previous lack of uniformity of identifying designations. This confusion will be eliminated if the manufacturers and users of relays employ the terms given in the paper, which have been approved by the Standards Committee of the Institute.

The first paper of a series contemplated by the Protective Devices Committee was presented three years ago. This is the second paper. Both of these deal with transmission line relay protection, and the Committee now plans to broaden its work to include also relays for protection of apparatus with the expectation of presenting additional data before the Institute as the art progresses.

The entire basis of the present paper is the experience of operating companies as reported by their engineers. The general theory of relays has been almost completely disregarded.

The use of combination over-current and directional schemes has become common due to the very satisfactory results that have been obtained with these relays.

Differential current schemes for parallel lines are increasing in popularity on account of their freedom from a-c. potential connections. Their use is limited, however; the differential power method using directional relays is suitable in those cases where the simpler current balance is not. The tendency appears to be in favor of balancing parallel feeders wherever possible to secure freedom from faulty operation on through faults together with quick action in case of trouble on one of the group. A number of different schemes, based generally on the same principle, is described in considerable detail.

The split conductor protection, though apparently successful, does not seem to be extending greatly beyond the early installations in this country, principally on account of the high cost of the cable.

Pilot wire protection, while abandoned by some operators, is being tried out in newer forms by others with some apparent likelihood of future extension.

The use of ground relays has been considerably extended particularly on systems having neutrals grounded through a comparatively high resistance. The application of these ground relays with regard to current and time settings is based on the same principles that apply for the relays connected in the phase. Both over-current and directional relays have been used with apparently successful results. By energizing only in case of accidental ground these relays may be set for much lower current values than the phase relays and in some cases at lower time values. The ground relays may be connected to sheath transformers or in the residual circuit of three current transformers of the usual type. Several applications of ground relays with pilot wire connections have been reported.

A very sensitive potential ground relay scheme for the protection of comparatively isolated circuits has been operating with good results for a number of years.

In one case, in order to avoid the necessity of installing grounding transformers, provision has been made to ground a second phase of the bus when it is shown by potential ground relays that an accidental ground has occurred on one phase. In this way a phase short circuit is produced permitting the faulty section to be isolated by standard over-current and directional relays.

An application of the combination of under-voltage and over-current relays is described. It takes into consideration the feature that the potential would be reduced proportionately as the faults is approached which adds a further degree of selectivity to the ordinary current method.

Accurate calculation of short circuit currents has proved highly desirable and considerable data concerning mathematical and mechanical methods of making these calculations are described.

General principles of relay application and practise concerning relay settings are discussed. Some notes are included relative to foreign practise and some of the outstanding features of installations in use in other countries have been described.

IN the paper on Transmission Line Relay Protection which was presented before the Institute in June 1919 there was included a proposed Relay Nomenclature. This with slight modifications was adopted by the Standards Committee on May 19, 1921. The approved nomenclature is as follows:

Classification According to Functions

Where relays operate in response to changes in more than one condition, all functions should be mentioned.

Presented at the Annual Convention of the A. I. E. E., Niagara Falls, Ontario, June 26-30, 1922.

Electric Protective Relay. An electric protective relay is an intermediate device, equipped with contacts to open or close an auxiliary circuit, by means of which one circuit is indirectly controlled by a change in conditions in the same or other circuits.

Directional Relay. A directional relay is one which functions in conformance with direction of power, or voltage, or current, or phase rotation, etc.

Power-Directional Relay. A power-directional relay is one which functions in conformance with direction of power.

Note: This includes both uni-directional relays with single-throw contacts and duo-directional relays with double-throw contacts. The reason this name is preferred to "reverse power" is that the device is frequently used to

function under normal direction of power. Furthermore, in some cases the normal condition of the system may permit power to flow in either direction. Relays for use in either alternating- or direct-current circuits are to be classed as power-directional relays.

POLARITY-DIRECTIONAL RELAY. A polarity-directional relay is one which functions by reason of a change in the direction of polarity.

PHASE-ROTATION RELAY. A phase-rotation relay is one which functions by reason of a change in direction of phase rotation.

CURRENT RELAY. A current relay is one which functions at a predetermined value of the current. These may be either over-current relays or under-current relays.

VOLTAGE RELAY. A voltage relay is one which functions at a predetermined value of the voltage. These may be either over-voltage relays or under-voltage relays.

POWER RELAY. A power relay is one which functions at a predetermined value of watts. These may be either over-power relays or under-power relays.

FREQUENCY RELAY. A frequency relay is one which functions at a predetermined value of frequency. These may be either over-frequency relays or under-frequency relays.

TEMPERATURE RELAY. A temperature relay is one which functions at a predetermined temperature in the apparatus protected.

OPEN-PHASE RELAY. An open-phase relay is one which functions by reason of the opening of one phase of a polyphase circuit.

DIFFERENTIAL RELAY. A differential relay is one which functions by reason of the difference between two quantities such as current, or voltage, etc.

Note: This term includes relays heretofore known as "ratio balance relays," "biased," and "percentage differential relays."

CLASSIFICATION ACCORDING TO APPLICATION

LOCKING RELAY. A locking relay is one which renders some other relay or other device inoperative under predetermined values of current, or voltage, etc.

TRIP-FREE RELAY. A trip-free relay is one which prevents holding in an electrically operated device such as a circuit-breaker while an abnormal condition exists on the circuit.

AUXILIARY RELAY. An auxiliary relay is one which assists another relay in the performance of its function and which operates in response to the opening or closing of its operating circuit.

SIGNAL RELAY. A signal relay is an auxiliary relay which operates an audible or visible signal.

GENERAL QUALIFYING TERMS

INVERSE TIME. Inverse time is a qualifying term applied to any relay indicating that there is purposely introduced a delayed action, which delay decreases as the operating force increases.

DEFINITE TIME. Definite time is a qualifying term applied to any relay indicating that there is purposely introduced a delayed action, which delay remains substantially constant regardless of the magnitude of the operating force. (For forces slightly above the minimum operating value the delay may be inverse.)

INSTANTANEOUS. Instantaneous is a qualifying term applied to any relay indicating that no delayed action is purposely introduced.

NOTCHING. Notching is a qualifying term applied to any relay indicating that a number of separate impulses are required to complete operation.

In addition to the standardized nomenclature, used throughout this paper, it was found desirable to adopt uniform terms for use in describing devices and characteristics of devices and systems which have heretofore been known by more than one name.

In order that there may be no misunderstanding as to use of these terms the following definitions are given:

DIFFERENTIAL RELAY. Explanatory note. In a differential relay the resultant force operating the relay, may be obtained by mechanical, magnetic or electrical means. Thus a relay is described as a mechnical differential relay, a magnetic differential relay or an electrical differential relay.

PERCENTAGE DIFFERENTIAL. Percentage differential is a term descriptive of the operating characteristics of one class of differential relay and indicates that the relay requires an increasing difference to cause operation, which difference will approach a definite percentage of either or both of the opposing quantities.

PICK-UP VALUE. The pick-up value, expressed in current, voltage, etc., is the minimum value at which the relay will complete its function.

DROP-OUT VALUE. The drop-out value, expressed in current, voltage, etc. is the maximum value at which the relay starts to rest.

BALANCED AND RESIDUAL CURRENTS. The currents in the several wires of a circuit are divided for convenience into two classes of components, "balanced" and "residual."

The "balanced currents" are those wholly confined to the wires of the circuit. Hence, their algebraic sum is zero at every instant.

The remaining components of the currents in the several wires which exist under conditions other than perfect balance, are termed "residual." The sum of the residual components is the "residual current" of the circuit. It is equivalent to a single-phase current in a circuit having the wires in multiple as one side, and the ground as the other.

Mathematically expressed, the residual current is the vector sum of the currents in the several wires, while the balance currents are those components whose vector sum is zero.

INTRODUCTION

As the quality of the service rendered by central stations becomes better the standard of service demanded by the public becomes higher. The only way of meeting this demand is by constantly improving protective devices and their application so that a fault in the system will be confined to the smallest possible area with the least possible disturbance to the healthy sections of the system.

It was in the hope of seeing such results realized that the Protective Devices Committee, several years ago, began a systematic study of the problem of protection. As a result, a Paper on Transmission Line Relay Protection was presented to the Institute in June 1919, being the first of a proposed series, covering the investigations of the Committee. In this first paper were incorporated a recommendation on standard relay nomenclature, a statement of the methods followed in approved relay practise and descriptions of such schemes as were considered as standard at that time because of successful operation.

No attempt was made to describe the many special schemes then on trial but early in 1920 a request was sent out to a number of operating companies, asking for information on transmission line relay schemes, which were being, or had been, tried out and proved

successful or abandoned as worthless. This particular method was adopted as the most efficient means of adding to the data on hand as presented in the previous paper, and of getting an accurate idea of the latest developments as well as an idea of the general tendency in the art of relay protection.

The Relay Subcommittee of the Protective Devices Committee, has as its function the keeping of an authentic record of the development and operation of various protective relay schemes. It is hoped that by presenting before the Institute, from time to time, such important data as may be gathered, duplication of effort among engineers may be avoided and the standardization of protective relays and schemes, fostered. Most of the central station companies, to whom the request for information was sent, manifested an interest and a desire for cooperation by replying promptly. Replies from others came in more slowly and it is only within the last few months that all the replies were received. On account of this the information given in some of the earlier replies was more or less out of date by the time the last ones came in. Therefore, when the work of compiling the data and coordinating it into the form of a paper was begun, the Committee where necessary asked for additional data on such schemes as it was thought desirable to include in the paper. Request was also made for data on any schemes planned or installed subsequent to the original inquiry. It is, therefore, believed that data contained in this paper are complete up to within a few months of the present date. There are probably some schemes with which the committee was not acquainted and it is possible that some companies may have operating data, besides those given, on schemes which are described.

In the previous paper an attempt was made to emphasize the desirability of setting relays for short-circuit current values, rather than on the basis of load current as was once common practise. Since that time important developments in methods of determining short-circuit current values have been made and it was thought fitting to give, in this paper, a description of the various methods used. Both the mechanical and mathematical methods are discussed with the advantages and limitations of each, and consideration is given to the factors which must be taken into account in making the determination.

Following this it also seemed advisable to add some observations on the best practise in making relay current and time settings as well as on the factors to be considered in making such settings. A few notes are also made regarding foreign practise with comparisons to American practise, where possible.

The recommendation on relay nomenclature made by the Protective Devices Committee in 1919, has been approved, with slight modifications by the Standards Committee and is now finding its way into general use. Having taken this step in the direction of standardization there now appears to be a need for some form of standard symbols for representing various types of protective relays in schematic, single-line and detail diagrams. In going over the diagrams submitted to the Committee, such a great diversity of symbols was found that it was sometimes difficult to understand the schemes and to determine their relation to other schemes. It is believed that a convenient standard symbol can be devised to represent each type of relay, thus eliminating a great deal of confusion and making all diagrams easily readable. It is the intention of the Committee to devote some time to this problem in the near future.

In addition to the difficulty experienced on account of the many symbols used, there was also some trouble in classifying various schemes because of great variety of names used in describing them. In order that such confusion may be avoided in presenting these schemes the Committee has divided them into five main classifications as follows:

1. Schemes using over-current and directional relays in combination.
2. Differential current schemes
3. Differential power schemes
4. Ground relay schemes
5. Schemes using over-current and under-voltage relays in combination.

All the schemes submitted may be placed in one or the other of these classifications. The subdivisions, however, were found to be more difficult and while the Committee has grouped the schemes in what seems to be the most logical manner, it is not intended that the designations used shall be taken as recommendations. It is believed, however, that the standardization of terms used in describing schemes would be very advantageous and it is hoped to make this the subject of a future study by the Committee.

The investigations by the Committee, as covered in both the previous and present papers have been confined altogether to transmission line relay protection. Some study has been made, from time to time, on apparatus protection but this was usually the result of an inquiry on some specific problem and the information was given out in the form of a letter.

It is intended, therefore, next to undertake to collect and coordinate data on the protection of apparatus and on special relay devices and schemes such as are used in remote-controlled and automatic stations. Such data will be presented to the Institute in the form of papers.

In replying to the request for information practically every central station company gave a description of all relay schemes which it has used, both standardized and otherwise. Some schemes which were considered as tried and proved by some companies were described as trial installations by others. It will, therefore, be found that some of the schemes described in this paper as being on trial, may be considered standard

by some engineers. It was thought best, however, to include all schemes reported as being on trial and at least one is described which was discussed in the previous paper.

In comparing these last replies to those received several years ago there was found to be a noticeable increase in the use of the schemes described in the previous paper. It was also apparent that a greater number of companies were using the approved methods of setting and testing relays. Almost every company reported that good results were being obtained with such schemes and not a few reported that older schemes and types of relays which were not giving good results were being replaced by more recent schemes using modern types of relays.

That there is considerable activity in the experimental field is shown by the number of new schemes now on trial. With the increasing size and complexity of the modern power system and with the varied conditions of operation introduced by interconnection and concentration of tremendous amounts of energy in small areas, new problems are constantly arising and new schemes must be devised to take care of the requirements. It is quite noticeable that, where possible, tried and proved schemes are being used but when these fail new ones are devised and tried out. Such schemes usually require a period of a year or more to determine whether they are effective and in the three years since the previous paper a considerable number of schemes have been brought out to take care of conditions not so pertinent at that time. The number of schemes and the record of their operation have been sufficient to determine in a general way the tendency in principle and design of protective relay schemes. As can be seen from the descriptions given later, the trend in development is toward the selection of defective lines by the use of differential schemes operating on the fault or trouble current rather than by relying altogether on the use of progressive time settings and current settings made on the basis of the line current. This is the natural result of the increase in the size of systems as to capacity, area covered, and number of stations operated in parallel. Beyond a certain point progressive time settings necessitate maximum time intervals which are so high as to become impractical, especially where sensitive synchronous apparatus is involved. The need for schemes which do not require progressive time settings and which will disconnect the faulty section with the least possible delay, has thus become imperative. Therefore, the greatest development seems to be in the use of the differential current and differential power principles in which the defective line is disconnected instantaneously and in which the equipment on one section is not affected by trouble in another section. The success with which such schemes are being used gives proof of the soundness of the principle and holds promise of even better results in the future.

Considerable attention has been given to the problem of disconnecting grounded feeders. This problem has become especially important because of the more general practise of grounding of systems, particularly where a comparatively high ground resistance is used, resulting in ground currents which may be less than full load value. This has made it necessary to devise schemes which will disconnect the grounded line before the trouble develops into a phase-to-phase short circuit. Especially is this necessary on overhead lines in order to prevent the trouble from spreading to adjacent circuits.

Another problem, which has resulted in the development of a very effective scheme, is that of detecting and disconnecting a grounded feeder on systems having an ungrounded neutral. In a great many instances it is found impractical to ground a delta system and this development offers a comparatively simple and inexpensive solution to the problem of grounds which might later develop into cross short circuits ordinarily resulting in serious interruptions.

Some schemes which are reported as trial installations are only modifications of schemes which were described as standard in the previous paper and in most cases these modifications were made to take care of some special condition. In describing the schemes an attempt has been made in each case to give the reason or special condition which prompted its development and application, the principle of operation, a description of the apparatus used, a summary of its operating results and its advantages and disadvantages.

The request for information was sent to about sixty operating companies in all parts of this country and Canada and in response thirty-five more or less complete replies were received. Of these reporting companies, thirteen have systems supplying city loads exclusively and twenty-two have either long distance transmission systems or have an extensive high-voltage network. This paper is the result of a careful analysis of the data submitted in the replies and schemes described are representative of the best American practise.

Description of Relay Schemes for the Protection of Transmission Lines

I. Over-current and Directional Schemes.

The use of over-current relays, either alone or in combination with directional relays, to obtain protection strictly on the basis of current intensity, time and direction is too well known to warrant repetition. However, two of the more unusual modifications are given.

Inverse Time Over-Current and Directional Relays

One of the large power companies having a system comprised in part of approximately eight sections in ring formation, together with a number of interconnecting circuits into which power is fed at six principal points, has found that in order to secure selective action under various operating conditions a very in-

verse time characteristic was required for the over-current relays. The ordinary method of time grading was not considered satisfactory because with changing generating conditions and the frequent opening of some circuit the general power distribution was sufficiently disturbed to alter the order of the time grading required. Due to the number of lines involved, however, at most of the stations it was found that the circuit in trouble would in nearly all cases carry a materially greater current than any other contributing circuit. Use of an inverse time characteristic which continued to give the necessary degree of selectivity for this natural difference in current over the complete range of probable faults was finally adopted.

In some cases definite minimum time was also required and at one point a rather high definite time was provided for very low current values, changing later into the inverse time. This unusual characteristic was required in order to permit operation at comparatively low current values as these would be limited due to the very long time involved if the fault were at the far end, whereas, for a short circuit close to the circuit breaker in question, the current would be of such large proportions that delay in tripping would be dangerous besides placing in jeopardy the other contributing lines. It was this latter consideration that required the inverse portion.

The directional relays were of standard types applied in accordance with usual practise.

The Use of Automatic Bus Sectionalizing to Reduce the Duty on Oil Circuit Breakers

In at least one case it was reported that the system had grown to such proportions that, in order to use circuit breakers then installed, it was decided to automatically sectionalize the buses in some stations and thereby limit the current to be interrupted in case of a fault. In such schemes no special relays are necessary, the standard over-current directional combination generally being used. General practise, however, seems to require that, wherever possible, circuit breakers shall be capable of interrupting the maximum power which may flow through them in case of a fault.

II. Differential Current Schemes. The balancing of parallel groups so as to provide sensitivity for faults within the group and, at the same time, safeguard against action for all other faults appears very successful. Its popularity is still further increased, whenever conditions permit, by the elimination of all alternating current potential connections as is done in the various differential current schemes reported.

Differential Current Protection for Two Lines

One company uses a differential current relay scheme which is interesting because it is an elementary form of a more complete scheme, operating on the same principle, and described elsewhere.

The application is made to paired 60-kv., 4/0 lines, 175 miles long, forming a bus for a complete transmission system. These lines are connected to power plants at five different points with a total generating capacity of 161,000 kw. Previous to the installation of these relays the transmission system was operated so that each substation was supplied from only one source of energy as attempts to operate the lines in parallel had resulted, in some cases in serious interruptions to service due to the splitting up of the system.

For proper functioning of the relay system more current must flow in the faulty line than in the healthy line. The differential current relay consists of two similar solenoids with movable cores suspended on an arm pivoted at the middle point. Two sets of contacts are mounted in such a manner that the throw of the arm in either direction, due to excess current in one solenoid, will close a contact. One solenoid of a differential current relay and one induction type over-current relay are connected in series with a current transformer. Each set of contacts on the differential relay is connected in series with the contacts of a corres-

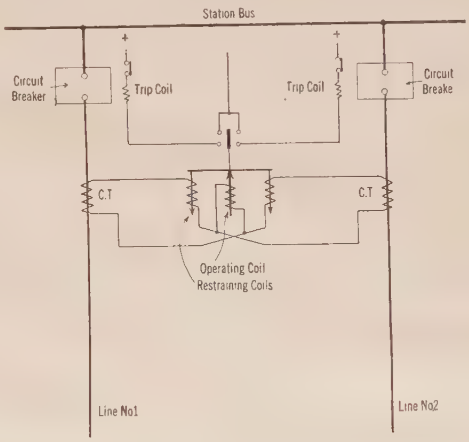


Fig. 1—Selective Differential Relay Scheme for Two Parallel Lines

ponding over-current relay. The contacts of the over-current relays, however, are normally short-circuited by a pallet switches in the circuit breakers when the breakers are closed. Thus the differential relay will discriminate between lines in case of a short circuit or ground involving only one line. When the faulty line is cleared, the opening of the circuit breakers on this line removes the short circuit on the contacts of the over-current relays, and the differential relay, having only one solenoid excited, closes the contacts to complete the tripping circuit. Thus, over-current protection is automatically cut into service on the remaining line when one line is out of service.

Satisfactory operations have resulted from the use of the differential current relay in cases of trouble which it was desired to clear.

The principal advantages of this scheme are the elimination of potential transformers and time settings. It also permits the isolation of the fault in the minimum time.

The disadvantages appear to be the extreme sensitivity under balanced condition which may result in faulty operations. There is also the necessity of providing additional protection for bus or substation troubles if such protection is desired.

This relay scheme will only function properly where an unbalance of currents is assured under all faulty conditions.

Selective Differential Relay Schemes

The relay illustrated in Fig. 1 operates to trip that one of a pair of parallel lines which carries the greater current in case the pair becomes unbalanced due to a fault. The relay in most cases requires an unbalance of at least normal load and for higher currents this unbalance must exceed some percentage of the smaller of the two currents. This is generally in the neighborhood of 25 per cent, thereby automatically compensating for normal unbalancing, such as may be present when slightly different lengths of line are involved, or a difference such as is occasioned by mutual inductance of overhead lines which frequently has a varying effect at times of faults of different characters. This percentage of unbalance is also capable of adjustment in order to further compensate for any known differences in characteristics of the lines involved, it not being necessary to maintain the same slope on both sides.

As mentioned above, this relay operates to open the circuit breaker of the line carrying the greater current. Therefore, it is perhaps always applicable to outgoing parallel circuits which are sufficiently balanced under normal conditions but should never be used on incoming lines where the line in trouble will not carry the greater current as, for instance, would be the case for a substation supplied by no other source of power. This would require that the good line supply whatever current might be taken by the connecting substation load as well as the fault, and would result in tripping the wrong breaker.

The relays consist of three coils whose plungers are attached to a balance arm on which the contacts are mounted. Current through the two end coils tends to hold down their plungers. The center coil is differentially connected or wound and with a current of equal value in the two windings no force is exerted on the plungers. The plunger of this coil has an adjustment for pick up value. When a fault occurs on one line, the force in one end coil and in the middle coil increases, so that the one end coil holds down that end of the arm while the middle coil raises its plunger and pivots the arm about the end coil, thus making contact in the proper direction to trip out the defective line.

The one company reporting the greatest experience, under actual operating conditions, with this type of relay installs them in some instances on incoming lines to buses which are supplied with abundance of other power, thus accounting for the good record reported.

This same company has in some cases four and six parallel lines between stations protected in this way, the lines being grouped in two or three pairs, each pair arranged as indicated in Fig. 1. Any odd lines are provided with time over-current protection having a comparatively low time setting. This appears to have no particular disadvantage where other contributing lines are generally balanced because of the instantaneous action on the balanced groups and the safeguarding against operation of the balanced groups for any fault which might occur in one of these odd circuits. Time over-current protection is automatically provided when one circuit of the balanced group is out of service.

There are 34 of these installations protecting 17 pairs of lines, some underground and some overhead and some combinations of underground and overhead. These circuits which have been in service for about 2½ years have been subjected to 37 faults, all of which have been cleared correctly without affecting other lines. On the other hand, 900 additional relay operations were reported on other contributing lines, involving a total of 1500 miles of circuits, in no case of which did these selective differential relays operate incorrectly. On

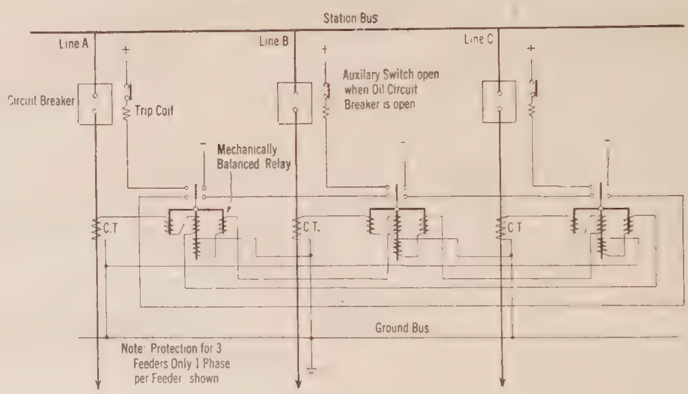


Fig. 2—Schematic Diagram of Selective Differential Relay Scheme

that part of the system not protected in this way this company reports 85 per cent correct operation, counting doubtful operations in general as being incorrect.

A second company has very recently installed equipment similar to that shown in Fig. 1, except that it is modified to include a fourth similar relay, connected in the same manner, to the neutral lead of the current transformers to operate more sensitively in case of grounds. No operating data are yet available.

The third company, reporting the use of these relays, made no particular comment regarding their operation. The general statement that all relays on the system operated 90 per cent correctly does not give any clear indication of the success of this particular installation.

This same general method of protection has also been extended in the case of one company to the protection of three lines in parallel as illustrated in Fig. 2. It will be noted that in this case each line is balanced with each of the other two lines so that in order to disconnect one breaker it must carry a greater current than

either of the two companion lines. This is insured by the tripping contact connections which are made so that both relays connected to the line in trouble must operate before its breaker can be tripped. It will be observed that this furnishes an additional slight advantage over the simple two-line group although the extra relays and connections are in most cases considered unnecessary.

The three open-wire lines, on which this scheme is used, were installed to operate in parallel with four split-conductor cables between a generating station and an important substation, and protection for the open-wire lines, comparable to that afforded the cables, was desired. It may be mentioned, as a matter of interest, that in order to parallel these open-wire lines and split-conductor cables, special precautions had to be taken on account of the large difference in reactance. By using external reactance it was possible to adjust them so that the characteristics were approximately the same, thus making parallel operation practical.

These three circuits also have over-current relays to clear bus short circuits and to give protection when only one or two lines are in service. When two or three lines are in service both types of protection are used but when only one line is in service the balanced relays are cut out. As it is sometimes necessary to operate with only one of these lines in service it was found convenient to install a single switch which will break the trip circuits to all the selective differential relays so that it will not be necessary for the operators to open a number of test switches to cut the relays out of service.

The relays are tested by passing current through one of the end coils and one winding of the middle coil, the plunger of the latter being adjusted for the desired pick up value. The phasing of the relays is most conveniently checked with a four quadrant power factor meter as described on page 851 of the A. I. E. E. TRANSACTIONS for 1919.

These installations have been in service since August 1919, and while there has been only one operation this was a correct one. A pothead failed and the defective line was cleared successfully without taking any other line with it.

Insofar as this particular company is concerned no tests have been made to duplicate operating conditions and as there has been but one case of trouble since the installation, the evidence is not considered sufficient to form conclusions regarding the selectivity of the scheme when called upon to isolate the faulty line of the three, nor is there sufficient data to indicate any advantages or disadvantages in operating characteristics. It is, however, considered to have the following inherent characteristics:

1. Instantaneous selectivity.
2. Freedom from potential transformer connections.
3. It has a percentage differential action which automatically compensates for normal unbalancing.
4. It does not afford protection against bus short circuits, requiring additional relays if such protection is desired.
5. Protection is not given when only one line is in service, requiring additional relays if such protection is desired.
6. It cannot be applied at the substation end of duplicate lines where there is no additional source of power at the substation end, as in such a case the fault currents in the two lines will be equal.
7. It is somewhat complicated and expensive in wiring when used on more than three lines.

No changes are contemplated to improve the installation though it will be retained until more data are obtained. It is believed that the failure of the relays to operate on numerous though short circuits indicates that they are satisfactory in this respect.

Selective Differential Scheme Using Induction-Type Relay

Another company reports that it has already completed the trial of a selective differential scheme which it now considers thoroughly proved. It differs in principle from the foregoing in that induction type relays are used, although it is applied to duplicate lines in practically the same manner.

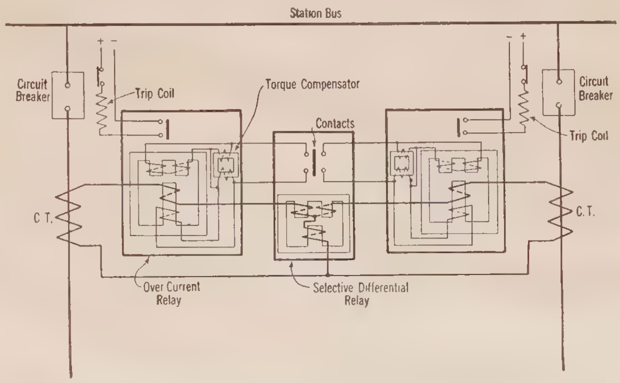


FIG. 3—SELECTIVE DIFFERENTIAL SCHEME USING INDUCTION-TYPE RELAY

Referring to Fig. 3, the scheme makes use of one differential relay connected between the two lines with an over-current relay in each line, so that the system will be sectionalized even if trouble should occur on the station bus. This also makes each line automatic after its companion line has been cut out of service. It will be observed that the differential relay does not directly trip the circuit breaker, but is arranged to decrease the time setting of the proper over-current relay, thus allowing this latter relay to trip out its circuit breaker. The over-current relay is of that induction type which is equipped with the so-called "torque compensator" for the purpose of giving it a definite time of operation. This "torque compensator" is short-circuited by the operation of the differential relay, thus allowing the over-current relay to operate very quickly. When one line is out of service,

the differential relay is disconnected and the over-current relay will operate in the time for which it is set.

There are about thirteen pairs of lines protected on both ends by these relays, some of which have been in service for three years. There have been about 50

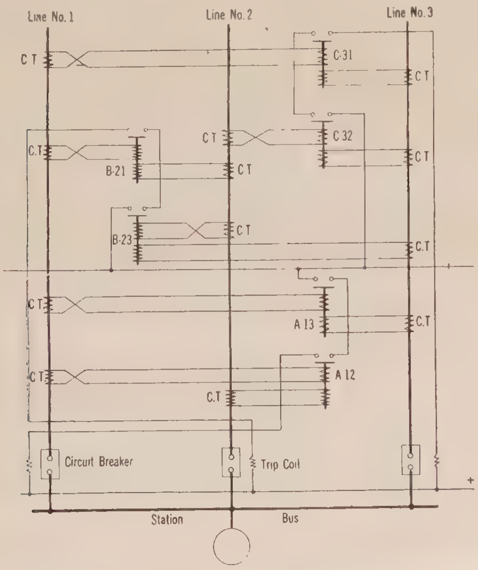


Fig. 4—Schematic Diagram of Differential Current Relay System as Used on Three Parallel Lines

correct operations and no interruptions to service due to incorrect operations, although one pair of lines which are not duplicates, and therefore not balanced, have tripped out several times on through short circuits. Improvements are now being made which are expected to overcome this difficulty.

This scheme has the advantage of being quick in operation and it does not require the use of potential transformers. It is particularly useful on tie lines between generating stations.

It has the disadvantage, inherent to all differential schemes of a like nature, in that it requires interlocking circuits between the circuit breakers to prevent operation when only one line is in service. It likewise cannot be used on the substation end of duplicate lines unless there is an additional source of power in the substation.

When used on a system which is grounded through a high resistance four relays may be used, three being for the purpose of clearing phase short circuits and the fourth, wound to operate on smaller currents and connected in the neutral wire between the two banks of current transformers, for clearing faults to ground.

Differential Current System for the Protection of Three or More Parallel Lines[1]

One company reports the installation of a differential current system for the protection of three or more parallel lines. It was adopted because of the desirability of selecting and clearing the defective line instantaneously, on account of the extremely sensitive character of the synchronous load on the system. It was installed first on four parallel feeders between a generating station and a substation. These feeders operate at 12,000 volts and are ungrounded, the system being delta connected. Later it was installed on four 60,000-volt lines 80 miles long. This part of the system was also delta connected and ungrounded.

The principle of this system of protection is based upon the fact that the current of a line becomes unbalanced relative to the same phases of other parallel lines when a fault occurs on it, whereas the current in the other parallel lines will remain balanced with respect to each other. This will hold true for a short circuit at any point on a system of three or more parallel lines provided their characteristics are not appreciably different. Therefore, an arrangement of differential relays coupling a feeder with other parallel feeders and having the trip circuits of these relays interconnected in such a way that their joint action will trip the unbalanced feeder, will be able to select and clear such a faulty feeder without disturbing the remainder of the system. The action of the relays will occur either simultaneously at both ends of the line or in succession depending upon the location of the fault.

Fig. 4 shows a schematic diagram of the scheme, operating on this principle as applied to three parallel lines. Line 1, for instance, is protected by the joint action of the two differential relays *A*-12 and *A*-13 responding to a line current difference between the lines.

Whenever a fault develops in Line 2 or 3, Line 1 becomes unbalanced with respect to the faulty line

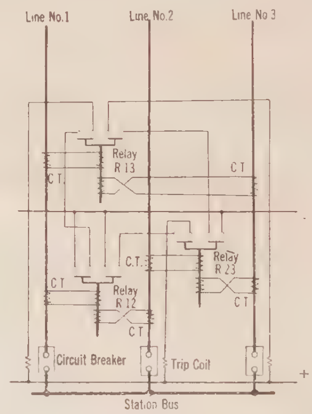


Fig. 5—Schematic Diagram of Differential Current Relay System for Three Lines Using One Relay per Line

and causes the corresponding relay to trip. Line 1 will remain balanced, however, with the other sound line, and as a result the sound relay will remain open thus preventing Line 1 from being tripped out. Should the fault be on Line 1, it will become unbalanced with respect to Lines 2 and 3, resulting in the action of

1. "Relay Protective Features of Toronto Power Company's Transmission and Distribution System" by P. Ackerman. The Engineering Institute of Canada. April 14, 1921.

relays A-12 and A-13 and tripping out the defective line. In a like manner, relays B-23 and B-21 provide protection for Line 2 and relays C-32 and C-31 for Line 3.

With the arrangement shown in Fig. 4, six differential relays are required for the protection of a three line system. It will be observed, however, that in the whole combination, two relays each form differential relays for the same two lines, the only difference being that the trip contacts of the two relays are inserted in two different trip circuits. By modifying the system as shown in Fig. 5, the number of relays required may be reduced by one-half. In this, each relay has two independent trip contacts, each contact being inserted in one of the trip circuits of the two lines from which the relay is energized. In actual practise only one current transformer is used for each line. The schematic arrangement showing each relay coil being fed from a separate current transformer, was chosen only to show clearly the relation between the various lines and relays.

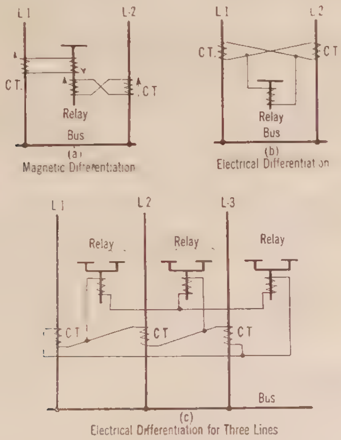


Fig. 6—Methods of Obtaining Differentiation

The same principle illustrated for the three-line system can also be applied to any system of more than three parallel lines. In any such case two ways are open to secure the same result. Either each feeder can be coupled with two parallel feeders to form the combination shown in Figs. 4 and 5, or each feeder may be coupled up with all parallel feeders. The latter method will require more relays but has the advantage in operation of permitting any line to be disconnected without disturbing the effectiveness of the protection so long as three lines remain in service.

Where two lines only are left in service, the protection will not be affected by through short circuits, but for short circuits within the section both lines are opened without discrimination.

With only one line in service a short circuit at any point on the system may open this line instantaneously.

All the differential relays shown in the foregoing diagram have been of the magnetic differentiation type, that is, relays with two independent current coils and normally bucking each other as shown in Fig. 6, (a). In a similar way electrical differentiation can be employed by connecting the current transformers in series and shunting the relay coil across them as shown in Fig. 6, (b). Fig. 6 (c) shows three-line protection employing electrical differentiation.

This scheme was installed on the four 60,000-volt lines in 1916 and remained in service until 1918 when this system was changed to two 90,000-volt lines. It then became inapplicable and was superseded by a scheme of double line protection, as described elsewhere.

As proof of its effective operation during the time of service the following summary of operation is given:

Thirty-two short-circuited lines were cleared successfully without a single case of incorrect operation, where one of the parallel lines only was in trouble. There was one case of trouble, involving two lines in a short circuit, which caused a total interruption. Only three lines were in service and the relays cleared both the faulty lines correctly, throwing the total load on the remaining line which tripped due to overload.

The scheme has been very effective in reducing the amount of synchronous load lost due to trouble. In twenty-eight out of the thirty-three cases less than 5 per cent of the synchronous load was dropped and in two other cases the loss was less than 10 per cent.

This scheme has also been installed on the 12,000-volt distribution system for all groups of three parallel feeders. The installation was based on the satisfactory results obtained on the 60,000-volt system and was put in with the double object of trying, in case of cable failure, to save the particular substation from total interruption and to obtain instantaneous clearance thus saving the remainder of the system from serious secondary disturbances.

On several occasions since this 12,000-volt installation, cable faults have been cleared successfully without loss of load. In some other cases the relay scheme has been unable to operate properly because of the failure of other apparatus. The less fortunate performance of the 12,000-volt system, therefore, cannot be attributed to the failure of the relays to function properly. The results on the 60,000-volt system are considered sufficient proof of the correctness of the principle and its effectiveness.

The chief disadvantages of this scheme are that it is somewhat complicated as to wiring, especially on more than three lines, and when only two lines are in service it is indiscriminating. Additional relays must also be provided to take care of bus short circuits if such protection is desired and with only one line in operation the differential relay setting must be above full-load current.

It has, however, the advantages of being free from the complications and uncertainty of action inherent to schemes using potential and is less expensive, especially on high-voltage systems.

Differential Current Scheme for the Protection of Two Parallel Lines[2]

One company reported the installation of a differential current system of protection for two parallel lines having generators or synchronous capacity at both ends. It was developed because of the necessity of obtaining some scheme which would clear the faulty one of the two parallel lines instantaneously. Such action was necessary on account of the very sensitive nature of the synchronous load on the system. The Nicholson arc extinguisher was previously used and it was found capable of saving interruption in about 75 per cent of all lightning short circuits but, as in practically all cases most of the synchronous load was dropped, the benefit derived from this device was only partial. From records of section operation of two circuits on a single tower line it was deduced that in only about 25 per cent of all lightning short circuits were both lines affected simultaneously. Thus in 75 per cent of the lightning short circuits a system of double line protection could be expected to clear the faulty line without interruption to the system.

Power directional relays, even if differentially connected, were not favored for this service because of the sluggishness and uncertainty of action on short circuits near the station. The Mertz-Price system was also excluded for practical and commercial reasons because of the length of the line.

A solution was, therefore, sought in a plain current differentiation between the same phases of two parallel lines, taking advantage of that fact that, with synchronous capacity at both ends, a short circuited line will manifest itself by drawing more current than the good line. This will hold true for a short circuit at any point between stations and a relay actuated by the excess current to trip the faulty line and simultaneously prevent the sound line from tripping, can select and clear the faulty line without affecting the service over the other line.

A schematic diagram of such a relay is given in Fig. 7 (a). The relay consists of two instantaneous elements so interlocked that the contacts of only one can be closed at a time. Short circuits outside the section so protected would act on the two elements with about equal force so that theoretically neither could make contact. In actual practise, however, one would invariably overcome the other and result in an incorrect operation. In order to overcome this difficulty an additional single-coil relay, energized by the differential current between the two lines, is used. This is shown in Fig. 7 (b), and its contacts are connected in series with those of the two-coil differential relays so that only joint action of the two can trip a circuit breaker.

2. "Relay Protective Features of Toronto Power Company's Transmission and Distribution System" by P. Ackerman. The Engineering Institute of Canada. April 14, 1921.

Thus any through short circuit, resulting in an approximately balanced current flow in the two lines, cannot actuate the single-coil differential relay. The trip circuits will, therefore, remain open even if the two-coil differential relay should be moved into one of the two contact positions.

In the case of a fault on one of the two lines, however, there will always be sufficient differential current between lines to actuate the single-coil relay and thus select, jointly with the two-coil differential relay, the faulty line.

With only these two relays there are certain conditions of short circuit under which the sound line would be tripped out immediately after the faulty line had tripped out at one end. It is, therefore, essential that the trip circuit of the sound line be opened before

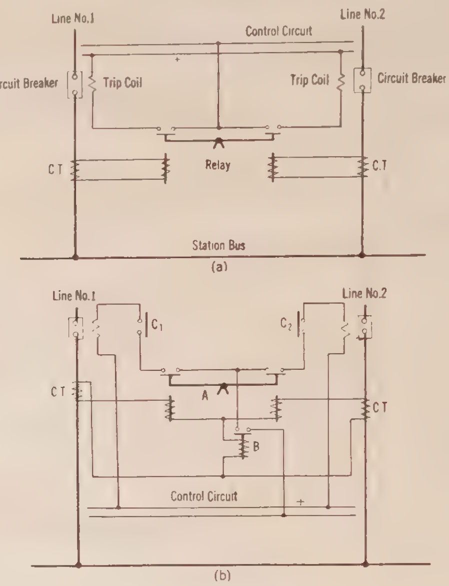


Fig. 7—Schematic Diagram of Differential Current Relay System for Two Parallel Lines with Generator or Synchronous Capacity at Both Ends

the faulty line has cleared. To do this an electrically controlled locking relay was adopted, energized by the oil circuit-breaker control in such a way that it opens the trip circuit of its line whenever the opposite line circuit breaker opens, and vice versa.

Referring again to Fig. 7 (b), *A* represents the relay which selects the faulty line and *B* represents the single-coil differential relay which prevents incorrect operation of the two-coil relay in case of through short circuits. *C*-1 and *C*-2 represent the automatic locking relays operated by the electrical control of the opposite line circuit breakers to prevent the sound line from opening immediately after the faulty line in case of short circuits at the extreme ends of the section.

Thus all conditions are taken care of and the scheme has proved effective for any kind of line short circuit when only one line was in trouble. It was installed first on two pairs of 60,000-volt lines, 80 miles long, and was operated in conjunction with the differential

current scheme for three or more parallel lines, as described elsewhere, until these four lines were changed to two 90,000-volt lines when the other scheme became inapplicable. This method of operation was followed about two years and as long as three or four lines were available the double line protection was used only during lightning storms or whenever other operating conditions arose which left only two lines in service. During lightning storms only two lines were operated as, on account of the insulators, only two were considered lightning safe.

Since the change to the 90,000-volt double line system the scheme has been in constant service. Operating records were available only from 1917 through eleven months of 1920, and during this time ninety-seven short circuits were cleared without a single failure, so long as only one line was involved. These short circuits were both single and three-phase and at every possible location between the two extreme ends of the lines. The reduction in the amount of synchronous load dropped during trouble was also very noticeable, being less than 30 per cent in all cases except eight and in most cases less than 15 per cent.

During this time there were fourteen cases of trouble in which the short circuit involved both lines and the relays were unable to function. Double-line short circuits were naturally to be expected because both circuits were on the same pole line.

The chief advantage of this scheme lies in its freedom from the use of potential transformers. This is especially desirable on high-voltage systems on account of the cost of these transformers. As disadvantages the following may be mentioned:

1. It is complicated in wiring and depends upon the correct functioning of three relays, each having a set of contacts in series.

2. Will not operate on bus short circuits, and additional relays must be provided if such protection is desired.

3. The last line is non-automatic unless the locking relays are arranged for automatic reclosing after a definite time interval. The last line would then have instantaneous protection provided the relays were set above the full-load current of the line, but would be affected by through short circuits.

Split-Conductor Cable System

One company reports four installations of split-conductor cable as follows:

1. Four 350,000-cir. mil cables between generating and substation.

2. Two 350,000-cir. mil cables between substations.

3. Two 2/0 cables between generating station and customer's substation.

4. Two 250,000-cir. mil cables between substation and customer's substation.

On Installation No. 1 the feeders are tie lines connecting a generating station with an important substation, and a scheme which would disconnect a defective line at an earlier stage in the development of the fault and more quickly than is possible with over-current and uni-directional relays, was required in

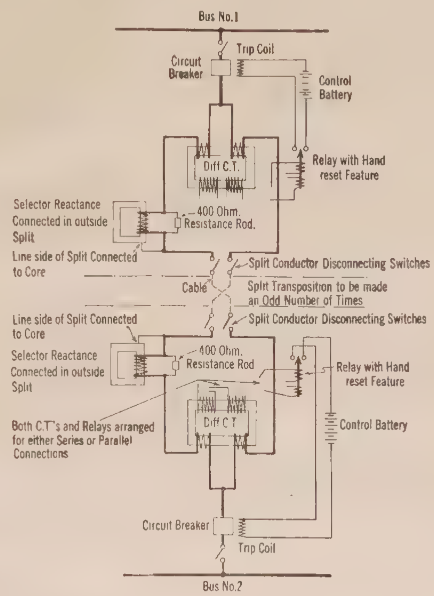


Fig. 8—Schematic Diagram of Split Conductor Scheme

order to reduce as much as possible the disturbance to such an important part of the system. Split-conductor protection gave promise of better satisfying these conditions than any other scheme. The other installations are paired radial lines and were installed

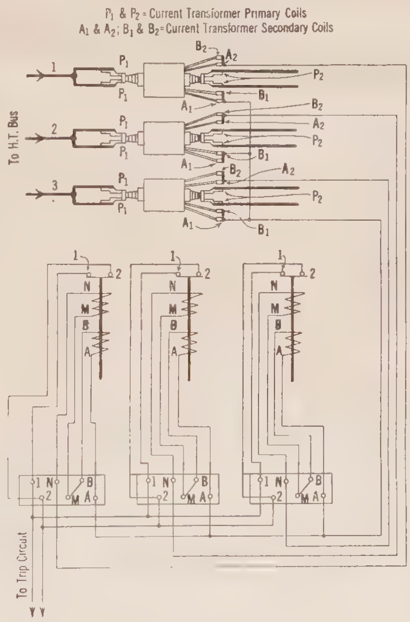


Fig. 9—Typical Wiring Diagram—Split Conductor Scheme

mainly to try out the scheme in other localities and under different conditions. Installations No. 3 and No. 4 supply customers who demand the least possible disturbance to their service.

A schematic diagram of the installation is given in Fig. 8 and a typical wiring diagram in Fig. 9.

The differential current transformers are made up of two primary windings, differentially wound, and a single secondary winding divided into two sections, giving a ratio of 4 to 1 when in series and 8 to 1 when in parallel.

Single-pole, instantaneous, over-current relays of the two-coil type with hand-reset contacts are used.

The reactance coils are of the iron-core type with a 500-ohm resistance in parallel, and the value of the reactance depends upon the length and size of the cable. They are of about the same size and form as the current transformers.

The lines of installation No. 1 are all operated in parallel. The other installations are paired radial lines, the lines of each pair being operated in parallel.

The relays may be tested for current balance by inserting a low scale ammeter in series with the relay winding while the cable is heavily loaded. The oil circuit breaker may be tripped at any time by opening one of the split disconnecting switches. It has been found that a setting for 10 per cent unbalance works out satisfactorily.

The time that each of these installations have been in service is as follows:

Installation No. 1	Feb. 20, 1918 to present date	
" No. 2	Sept. 29, 1917 " " "	
" No. 3	Jan. 6, 1918 " Aug. 21, 1920	
" No. 4	Sept. 29, 1917 " Dec. 28, 1918	

All these split-conductor installations have proved satifactory but only installations No. 1 and No. 2 are now in service. Installation No. 3 was discontinued after a cable failure, as split-conductor cable could not be obtained in as short a time as was necessary which necessitated its replacement by standard cable. Installation No. 4 supplied service to a large customer who closed down his plant after completing war contracts.

As proof of the effectiveness of the split-conductor scheme of protection the following summary of operation was given.

Installation No. 1—There have been no incorrect operations. There have been six correct operations.

Installation No. 2—There have been two incorrect operations. In the first case a fault on a line between the generating station and another sub-station opened both lines at both ends. In the second case the oil circuit breaker on another line at the generating station failed and opened both split conductor lines at both ends. Of the four split conductor installations, this is the only one to have incorrect operation and its is believed that there is an unbalance somewhere in the connections which was not evident when checked by the usual methods and which caused the relays to operate under heavy surge conditions or on through short circuits. This is to be carefully checked, by actual test if necessary. There have been no cable failures and, therefore, no correct operations.

Installation No. 3—No faulty operations have taken place. There have been three correct operations, in each instance the faulty line being tripped out without opening any other lines.

Installation No. 4—No cable or apparatus failures or operations, either faulty or correct have occurred.

In every case of cable failure the line was cleared at such an early stage in the development of the fault that there was no perceptible voltage dip or other form of system disturbance.

Up to the present time no tests have been made to duplicate operating conditions and the operations which have occurred indicate neither the necessity of such tests nor the need of any change in the trial installations except as mentioned in the summary of operations of installation No. 2.

From the experience which this company has had with this scheme of protection it is considered superior to the over-current and uni-directional scheme in the following respects:

1. It does not require tapered time settings for selectivity and thus may have any number of substations in a loop or in tandem.

2. It does not require the calculation of short-circuit currents for relay settings.

3. The cable is disconnected at an early stage in the development of the fault, generally before the cable is badly damaged and with practically no dip in the voltage or shock to the system.

4. A breakdown in the primary winding of the differential current transformer or in the reactance coil causes the line to trip out, thus indicating an apparatus breakdown at the time of its occurrence.

5. The scheme is applicable to any number of lines and additional lines may be added without any change in the wiring or relay settings of the lines in service.

It is also considered to have the following disadvantages:

1. It is more expensive by about 20 per cent than standard cable with over-current and directional protection.

2. It requires special apparatus. The reactance coils, differential current transformers, double disconnecting switches and cable are special and are usually of slow delivery, which may cause considerable delay and inconvenience in case of breakdown, unless sufficient material is carried in stock to take care of any emergency.

3. It does not protect against bus short circuits, necessitating over-current relays if such protection is desired.

Pilot-Wire Scheme Using Differential Relays

One of the companies has tried a pilot-wire scheme on the balanced voltage principle, that is the e. m. fs. of the current transformers at each end of the pilot wire are opposed to each other. However, after a thorough test of this scheme, it has been superseded by another pilot-wire system which its originator has called a

balanced differential system. This system makes use of a special differential relay having two coils with equal turns, and connected so that under normal operation the currents through these two coils are equal but in opposite directions. By reference to Fig. 10,

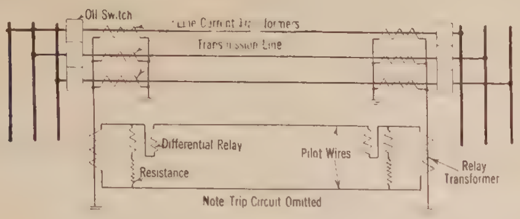


Fig. 10—Differential Relay Scheme—Two Pilot Wires

it will be observed that the current from one of the current transformers divides into two equal parts, one part going through one coil of the relay, thence through the pilot wire to the other station, while the other half of the current flows through the relay and through a resistance which is adjusted to be equal to that of the pilot wire. It is easy to see that under normal conditions, no matter how heavy the current may be through the feeder, there will be no unbalanced current through the relay attempting to operate it. However when trouble occurs in the feeder, the current from the transformer at one end of the pilot wire will oppose the transformer at the other end, and, therefore, it will not divide evenly, relatively less current flowing through the pilot wire and more through the resistance so that the magnetic balance of the relay will be upset, causing it to operate.

The system shown in Fig. 10 with two pilot wires will operate only when the cable fault involves current flowing to ground, but the system shown in Fig. 11, which requires three pilot wires, will operate no matter what may be the nature of the fault. It has been estimated that to protect a 5000-ft section of cable, the cost of the two-wire installation would be 90 per

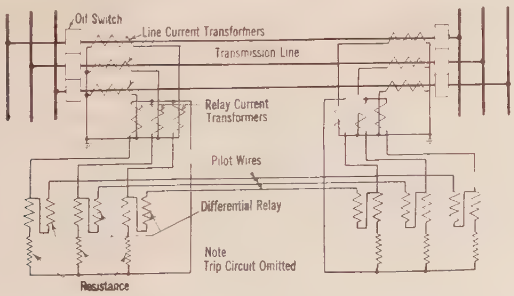


Fig. 11—Differential Relay Scheme—Three Pilot Wires

cent, and the cost of a three-wire installation 110 per cent of the cost of a standard installation of directional relays. For a 10,000-ft. length of cable, the cost would be respectively 135 per cent and 170 per cent of the cost of a directional relay installation.

This company's network is quite extensive and it was feared that on many of their loops, where a number of substations are in series, the total time setting required on some of the over-current relays, in order that they might be properly selective, would be so high that the conventional over-current directional scheme would not be suitable. This pilot-wire scheme was therefore selected for use on certain sections to secure instantaneous operation and thereby reduce the time required on other relays. Furthermore, since most cable troubles start on a breakdown to ground, this scheme will, in the majority of cases, disconnect the faulty cable before the trouble has developed into a short circuit.

Since August 1918, the scheme using two pilot wires has been applied to 60 lines and the three-pilot-wire scheme to four lines. There have been 28 correct and 12 incorrect operations, the latter being due largely to the defective apparatus which was used on the first few installations. It is interesting to observe the causes of the false operations, which can be grouped as follows:

Defective apparatus and connections	6
Errors in making connections.......	4
Unbalance in the current circuit due to instrument installations.......	2
Total.................	12

During the past two years there have been only two incorrect operations and it is reasonable to expect even less in the future.

The advantages of this scheme are:

1. Complete independence of relays on one line from all others.

2. Selective time settings are not required as the action is instantaneous.

3. High current settings are not required and short-circuit current calculations are unnecessary.

4. Special cable is not required as in the case of the split-conductor scheme.

5. The balancing operation is simple, requiring merely the adjustment of the series resistance.

6. Standard current transformers may be used and no high potential is induced in the line-current transformers.

7. The complexity of the network offers no difficulty in the application of the scheme except in the case of tapped lines.

The one disadvantage of this scheme lies in the cost of the pilot wire. For long transmission lines, induction type relays are preferable but for short lines or for a network this pilot-wire scheme has many advantages.

Differential Pilot Wire

One company reported that differential protection, using pilot wires, was originally tried out on several 110-kv. line sections but that it was abandoned because of very frequent interruptions which could not be satisfactorily explained.

On account of the high voltage of the system it was desirable to disconnect a faulty circuit instantaneously and this scheme was devised in the hope that it would meet the requirements. A schematic diagram of the installation is shown in Fig. 12. The longest section upon which it was installed was 51 miles and the shortest 13 miles. The neutral of the system was at first ungrounded, but was later grounded through a water resistance. One ground was located in the neutral of the step-up transformers and the other in the neutral of the step-down transformers at two places in the system.

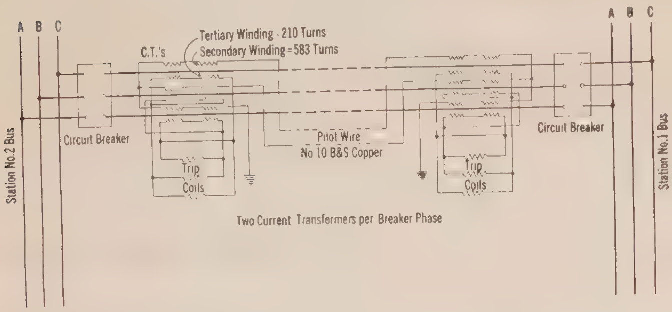


Fig. 12—Schematic Diagram of Differential Pilot Wire Relay System

The special equipment required for the scheme consisted of bushing-type current transformers with secondary and tertiary windings. Ordinary alternating-current trip coils of rather high impedance were used as relays.

Referring to Fig. 12, the operation was as follows:

Under ordinary conditions of flow of power, the current flowing out of the circuit at the receiving end should be equal to that flowing into it at the transmitting end. Under these conditions, the voltage induced in the secondaries of the bushing type current transformers would be equal and opposite, and currents proportional to the line current would flow in the delta-connected tertiary windings, with no tendency to flow through the trip coils in parallel with them, since the resultant of the line currents would be zero. Thus, when any current flowed from the transmitting end without reaching the receiving end, as would be the result of a fault, the system would be unbalanced, and current would be forced through the trip coils to operate the circuit breakers.

The scheme was in service about two years. No adequate records of the various tests or operations are now available, but it was abandoned as unsatisfactory about 1913. The use of the ground for one conductor of the pilot-wire system may have been partly responsible for the defective operation of this scheme. This may apply, especially, on account of exposure to the power circuit which would normally indicate the desirability of proper relative transpositions in the pilot-wire circuit. It is also possible that an attempt was made to have the equipment too sensitive, and as inverse time over-current relays with mechanical trip were used on the same lines, it is probable that these operated simultaneously with the differential relays and thus destroyed selectivity.

This scheme is described chiefly as a matter of interest since it constitutes the only reported attempt to use such a scheme on a high-voltage overhead system.

(To be continued)

The Dielectric Strength of the Vacuum

Electrostatic Ionization Gradient of Metal Electrodes

BY J. L. R. HAYDEN
Member, A. I. E. E.
General Electric Company, Schenectady, N. Y.

THE dielectric strength of air is 30 kv. per cm. at 0 deg. cent. and 76 cm. barometric pressure. It is proportional to the air density over a considerable range. It reaches a minumim in a moderate vacuum. Beyond this, it increases again, and in a very high vacuum reaches high values. much higher than at atmospheric pressure.

It is an interesting and important question, whether the dielectric strength increases indefinitely with increasing vacuum, and so approaches infinity for a perfect vacuum, or whether it approaches a finite limiting value in a perfect vacuum, and what is this value of the "dielectric strength of the vacuum." Electric conduction through a dielectric is explained as convection, either by electrons alone (electronic conduction), or by the electrons in combination with the atoms of the surrounding gas (Geissler tube conduction) or by the electrons in combination with the vapors of the terminal material (arc conduction).

There could be no conduction by an absolute vacuum. The dielectric strength of the perfect vacuum would be the voltage gradient which, by its electrostatic stress, expels from the electrodes ions alone or ions and metal vapors, in other words, the ionization gradient of the metal electrodes.

During the past few years the industrial development of the modern high power X-ray tube and of the kenotron, pliotron and other devices has led to the production of very much higher vacua than possible before.

It therefore appeared desirable to investigate the

striking distance between sphere gaps in the most perfect vacuum which we could produce with the methods now available.

F. W. Peek, Jr. and others have shown that it is not sufficient to have the breakdown gradient of the dielectric exceeded at one point, but that it must be exceeded over an appreciable range, the so-called "energy distance" or "ionization distance." Therefore tests with very short gaps, or with irregular fields, as point electrodes, are misleading in determining the dielectric strength[1]. The only reliable arrangement seems to be a gap between spheres, of a length of the same magnitude as the radius of the spheres.

In the following tests, one-centimeter spheres were used, and a gap of about two millimeters in the first three tests, about three millimeters in the final test.

The first three tests were made with a gap of 0.203 cm. between two one-centimeter spheres of pure molybdenum, in a 7-inch kenotron bulb. As the vacuum gradually improved, they gave the sucessive values of dielectric gradients:

1st test: 510 – 660 – 733 – 790 kv. per cm.

2nd test: 320 – 488 – 520 – 587 – 652 – 733 – 733 – 733 kv. per cm.

3rd test: 800 – 910 – 910 – 910 – 930 – 920 kv. per cm.

In the final series of tests, an eight-inch kenotron bulb was used.

The two spheres, and the shanks back of them, were of pure molybdenum, highly polished. They were heated in a vacuum to 1000 deg. cent. before being sealed into the bulb.

The diameter of the spheres was 0.983 and 0.997 cm. respectively, average 0.990 cm.

Their distance was measured electrically before the test by the 60-cycle alternating voltage required to jump the gap, and the average of four tests in close agreement with one another was found to be 0.307 cm. After the test, the distance was measured again, by a cathetometer, and gave 0.305 cm. This gives an average of 0.306 cm.

A tungsten filament was sealed into the bulb about three inches from the spheres. This was, during the exhaustion, heated to high temperature by a small highly insulated transformer, of high voltage (over 100 kv.), connected between spheres and filament, and the spheres heated to incandescence by the electrostatic bombardment from the incandescent filament, for the purpose of expelling the occluded gases from the spheres.

The bulb was connected to a high-power Langmuir pump through a wide tube (not capillary). A liquid air cooled mercury trap was inserted, and a liquid-air-cooled charcoal bulb connected to the exhaust tube close to the bulb to assist in absorbing the gases.

1. For instance, in very short air gaps (0.00012 cm.) between large spheres, we reached voltage gradients, at atmospheric pressure and temperature, as high as 2800 kv. per cm.

The bulb was heated to 425 deg. cent. for several hours during the exhaustion, the spheres bombarded to bright red heat from the filament, and then a voltage close to the breakdown voltage was maintained between the spheres, to expel occluded gases.

The exhaustion was continued for two days, cooling down for tests and then heating again.

Toward the end of the first day, the effective 60-cycle voltage required to jump the gap was 167 kv.

At 11:30 of the second day it was 196 kv.

At 2 p.m. of the second day it was 213 kv.

At 4 p.m. of the second day it was 213 kv. and did not rise any further.

I believe that with this, the most perfect vacuum which it is possible to get under the existing conditions had been reached, and that the bulb had been exhausted down to the vapor tension of the glass walls, and that any further improvement of the vacuum would be possible only by cooling the bulb by immersion in liquid air, thereby reducing the vapor tension of the glass walls.

An attempt was made to cool the bulb by liquid air, but it cracked by too rapid cooling, and as other more urgent work postponed the investigation, the data are limited to those given herewith.

The maximum voltage gradient of a sphere surface of a gap of length l between two spheres at radius r, is given by:

$$g = \frac{e}{l} f$$

where: $f = \frac{1}{4}\left(\frac{l}{r} + 1 + \sqrt{\left(\frac{l}{r} + 1\right)^2 + 8}\right)$ is the divergency factor of the field[2]. For the particular values of length l = 0.306 cm. and radius (r) = 0.495 cm. (average)

The calculated value of the divergency factor, $f = 1.219$

The final value of voltage reached was 213 kv. effective, or $e = 213 \times \sqrt{2} = 301$ kv. peak value.

The foregoing values substituted in the equation give for the maximum gradient, g = 1235 kv. per cm.

This is 41 times the normal dielectric strength of air.

It is 25 times the dielectric strength of air in the same gap between the same two spheres.

To summarize: A dielectric strength of 1235 kv. per cm. has been reached in an approximately uniform field of appreciable extension in a very high vacuum.

The dielectric strength of the perfect vacuum, or the electrostatic ionization gradient of metal electrodes, is not less than 1235 kv. per cm.

The auther acknowledges the assistance of C. C. Burger in making the tests.

2. See Dean, *Physical Review*. Dec. 1912, April 1913, *G. E. Review*, March 1913.

The Improvement of the St. Lawrence from the Viewpoint of Private Capital

BY HUGH L. COOPER

Consulting Engineer, New York, N. Y.

THE subject of the reconstruction of the St. Lawrence River, and the results to be obtained therefrom, lead us into magnitudes that are very difficult of practical visualization. In order that you may be properly oriented I would like to refer you to the map, Fig. 1. In the course of my remarks I will call your attention to a general plan which I have worked out for a part of this reconstruction, and will give you a general description of my ideas as to what should be done with the remainder of the river. It is my present belief that the best public engineer will ever be accepted for work of this magnitude, and that before any engineer's plans are adopted, they will have to pass successfully through the acid scrutiny of a high grade commission of engineers from Canada and America, the personnel of which, when examined, will show that the Commission is qualified to the fullest degree by previous experience, to write the verdict.

Divisions of the Subject

I desire to divide our St. Lawrence subject into the following divisions:

Fig. 1—Power Territory Available for St. Lawrence Power in Canada and the United States

Transmission line distances will average about 115 per cent of the distances shown by the circles that center at Dam No. 1. The territory within these circles and within circles that can be drawn using Dam No. 5 as a center can be served without invading any experimental field.

interest demands that the St. Lawrence River should be harnessed by the construction of five dams; the first one being located at Cat Island above Massena, the second at the foot of the Long Sault, the third at the foot of Cedar Rapids, the fourth at Cascades Point, and the fifth at Cote St. Paul.

Before we go further, I wish to tell you very plainly that I am not flattering myself that I have solved the St. Lawrence problem. Later, very necessary investigations may show that dams Nos. 1 and 2 should be combined. I believe that the judgment of no one

First, private capital personnel and proposal.

Second, the attitude of water power people toward navigation.

Third, with reference to the magnitude of the work as a physical structure.

Fourth, six new great values to the public from a reconstructed St. Lawrence River.

Fifth, how St. Lawrence benefits should be achieved.

Private Capital Personnel and Proposal

It has occurred to me that I should clear up the minds of this audience as to the honesty of a small amount of propaganda that still remains with us about

Address delivered at the Spring Convention of the A. I. E. E., Chicago, Ill., April 21, 1922.

the so-called water power trust. I assume that in the public mind, a proper definition of a trust would be an organization which could, because of its holdings either of rights, or property, or both, rob or hurt the people without hindrance of law. As I read a few of our newspapers, this definition seems to fit the case. The studies which I have been carrying out on the St. Lawrence for about three years have cost the interests that supplied the money, something over $250,000 for engineering research, and $500,000 more is ready to complete our investigations, as soon as governmental permits are granted. This money has been furnished by interests who own the Frontier Corporation of the State of New York. It is opportune to state here very plainly that the Frontier Corporation has never been engaged in any propaganda in the past, and will refrain from such methods in the future. We have not asked for, nor will we be seeking the support of any particular section of the press. When the St. Lawrence question is fully understood it will be regarded as a national problem in which the points of the compass must be omitted. As we are asked for our views by the press, by government officials, and by the general public, we will gladly give them the facts, and stop there. Our well defined expectations of success are based entirely upon the good sense and intelligence of our people to decide what is in the best public interest.

The members of the Corporation at this time are, the Du Pont Company, the General Electric Company, and the Aluminum Company of America. They have been brought together because of the belief that no lesser syndicate of successful men of industry could cope with the problem from a private capital standpoint. The carrying out of a project of the magnitudes here under consideration, will call for the very best intellects that America can produce, and the American people have a right to demand that when the St. Lawrence work is finished, by whomsoever it is constructed, the work shall represent a magnificent monument to American ability. Such a monument can never be expected to result from government ownership, or from the leadership, however earnest and honest, of merchants, railway men, lawyers, doctors, newspaper men, or others; it can be expected to come about only by the combined efforts of organizations which are familiar with the work to be undertaken, and whose records with great enterprises are successful.

The Aluminum Company of America, as you may know, has spent several millions of dollars in the purchase of lands along the Long Sault stretch of the River between its Massena intake and Cornwall. When the purchases of these lands were made, it was hoped at some future time to develop water power on this property for use in metallurgical chemistry. Over two years ago the Aluminum Company came to the definite conclusion that this great water power in the St. Lawrence was of far more value to the public if used for general distribution to little and big consumers, than it was of value to the same public through the consumption of aluminum, and some time after reaching this decision, the Aluminum Company passed the control of all its holdings to the Frontier Corporation.

At the time the Frontier Corporation was formed, over a year ago, and for some years before that time, all of our syndicate members were fully aware of, and in complete accord with the provisions of Federal and State Laws that require, individually and collectively, the most thorough supervision at the hands of public service commissions, state water power commissions, and the Federal Water Power Commission, of all of the energy that could be created from the St. Lawrence or any of our other navigable streams. Under the operation of these laws which I have just mentioned, the rates to be charged to consumers, the character of the service, the territory to be served, and the issuance of securities, are all in the hands of public service commissions, the servants of the consumers themselves.

The members of the syndicate have entered upon this endeavor with the full knowledge of all of the restrictions that I have just mentioned, and with which you are all so familiar, and to call such an association of men a "trust" or a "power ring" is plain dishonesty. No good person seeking the truth can ever accuse the Frontier Corporation, and the men behind it, of having anything but the highest aims in this whole matter. It is further proper to say at this time that the quantity of money required for the first unit of installation will be so great that the interests behind the Frontier Corporation, strong as they are, can never be anything but leaders and holders of a small minority of the total securities that will necessarily be sold. The majority of the securities will have to be taken by the public at large. This investing public will never subscribe to these securities if their attractiveness is clouded by propaganda of abuse and misrepresentation in any considerable amount. Before the Frontier Corporation, or any other corporation, can finance units of development on the St. Lawrence, it must prove to governmental authority, and its prospective investors, that its financial and engineering plans, after full official inquiry, have been found not only the best that can be devised in the public interest, but superior to all other plans considered.

The members of our syndicate have an abiding confidence in the ultimate fairness of American and Canadian people, and believe they will eventually accord us the approval we must have. We realize that much patience will be required on both sides, and we believe when the cards are all on the table, where they should be, neither the people nor we will have much to complain of.

Attitude of Water Power Toward Navigation

Over the St. Lawrence River there is now transported annually about 4,000,000 tons of freight, a few passenger steamers, and there is developed at present

from the St. Lawrence less than 200,000 horse power. For some time in the past, our friends of the opposition, in different places, have been trying to create a false impression regarding the attitude of the water power people toward navigation. This attempt was wrong because it was based upon falsehood. The opposition should have given us credit for more intelligence than to suppose that any group of men would, for a moment, consieer the mutilation of, or encroachment, in the slightest degree, on the great transportation facilities the Great Lakes and the St. Lawrence can offer to more than 40,000,000 existing people, to say nothing of the vast increase in this population future time will record. That navigation is paramount to power, every one concedes, and I know of no one who has ever disputed this view, whose opinion is worth noticing. The laws under which we are hoping to operate, specifically make navigation paramount to power, and require that all of the water levels in the pools shall be regulated in the interest of navigation, by government.

We have always known, advocated, and maintained that by the right of the people, by existing law, by common sense, and by every other avenue of good reasoning, power is secondary and incidental to navigation, now and always will be.

PHYSICAL MAGNITUDE OF THE PROPOSED PLANS

The stretch of the St. Lawrence River under consideration is 120 miles long from Ogdensburg on Lake Ontario, to Montreal, and drops, in this stretch, about 220 feet—approximately 200 feet of which is available for power purposes.

You are, of course, aware of the fact that the International Joint Commission, created by the Act of Congress, January 11, 1909, has recently made a report to the Governments of the United States and Canada, on the subject of the reconstruction of the St. Lawrence River, based upon the recommendations of their respective government engineers. Open criticisms were called for by the International Joint Commission of the Government Engineers' report, and I have filed with the International Joint Commission comments on the Government Engineers' report. I have found myself unable to agree in any sense with the recommendations of the Government Engineers, and believe the adoption of their plans would constitute a most extraordinary mutilation of a great international engineering possibility. This sweeping opinion is fully shared by every hydraulic engineer of experience I have consulted, and I have consulted several of them. I do fully agree, however, with the recommendations of the International Joint Commission to the effect that because the problem before the Commission was of such great magnitude, the whole subject should be referred to a new enlarged commission of engineers whose previous experience in work of this character would be acknowledged everywhere as of the highest acceptability.

I shall not take your time in an extended review of my differences with the Government Engineers' report, but will instead give you a very brief outline of what they have proposed, and what I have proposed, and will refer you to the comparative profiles shown in Fig. 2. The Government Engineers propose the installation of

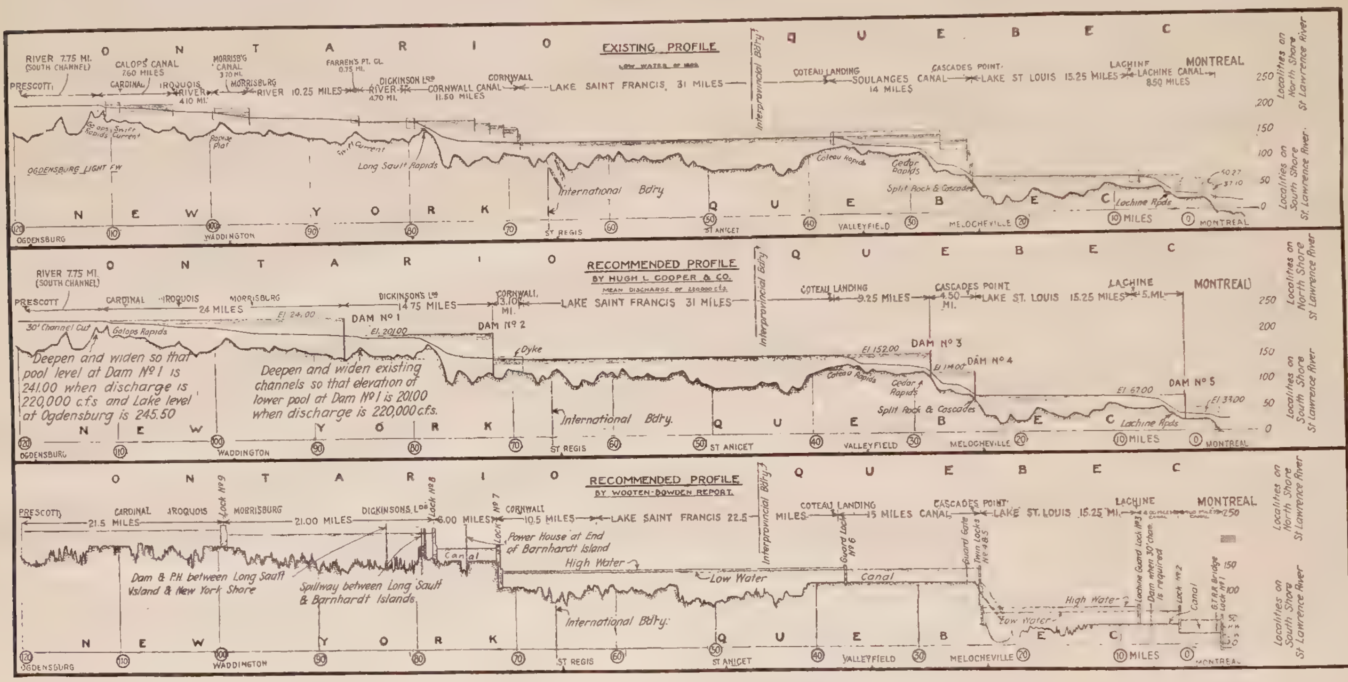


FIG. 2—THREE PROFILES OF THE ST. LAWRENCE RIVER

1. Existing profile.
2. Profile recommended by Hugh L. Cooper subject to such changes as final surveys require.
3. Profile recommended to the International Joint Commission for adoption by the Wooten-Bowden engineering report.

three dams in the St. Lawrence, nine locks, thirty-one miles of canals, and the installation of 4,545,000 horse power capacity, at a grand total cost of $506,000,000, without any interest during construction, or during the loading period for the power, and all of this for power houses that would, if operated to capacity, automatically shut down in times of ice attack. In my opinion, this $506,000,000 cost estimate is not only valueless because it excludes interest, which has to be paid as well as principal, but it is otherwise valueless because the estimate is on structures that sadly fail to produce the best efficiency either in navigation or power. My plans call for the installation of five dams in the St. Lawrence, six locks, six miles of canals, and 5,400,000 horse power capacity, at a total cost including all charges, from one billion, two hundred and fifty million, to one billion, four hundred million dollars, depending on results of final surveys.

I will now direct your attention to the Figs. 3 to 19 inclusive, which will illustrate better than words, the general power situation, as I see it.

Because of the greater ratio of pools to narrow canals, my navigation plans provide for 25 per cent greater speed, and much greater safety through the St. Lawrence than the Government Engineers' plans provide for. They have thirty-one miles of canals, and nine locks, where I have six miles of canals, and six locks. In all other navigation requirements, my plans are either equal or superior to the Government plans. In addition to producing far better navigation facilities than those proposed by the Government Engineers, my plans produce 855,000 more horse power capacity for general use, 550,000 horse power of which is in the international stretch of the river. The public in Canada and the United States will never consent to throwing away navigation facilities and power in the way the Government Engineers have recommended. Some day our St. Lawrence Tidewater Association friends will see and admit the inferiority of the Government engineering plans with respect to both navigation and power, and the superiority of our plans with reference to the same subjects.

Six New Great Values to the Public from a Reconstructed St. Lawrence River

The first value to the public from a new St. Lawrence, if Mr. Hoover, Mr. Barnes, and many other high authorities on this subject are correct, will be the creation of a permanent link in a navigation system capable of handling 200,000,000 tons of freight per navigation season. As soon as the Great Lakes district is completed to the same capacity as the St. Lawrence, there will thus be created the greatest inland navigation facility in the world, producing permanent distinct advantages to producers and consumers alike.

Second, the saving of coal and labor. As to the value of 5,400,000 horse power that can be commercially developed from the St. Lawrence River on a load factor varying from 70 per cent in the winter to 80 per cent in the summer, 1,200,000 of this horse power would belong to the United States by treaty right, and 4,200,000 to Canada by the same right. Inasmuch as Canada already has a superabundance of hydroelectric power in the vicinity of the St. Lawrence to supply her needs for decades to come, it is probable that at least a part of this power can be used in the United States until the Canadian markets require it.

The statistics of the United States Government show that 5,400,000 horse power will save more than 54,000,000 tons of coal per annum. It is difficult to visualize numerals of this magnitude. Using fifty-ton coal cars as a basis, 54,000,000 tons of coal would make a railway train 9000 miles long, a distance greater than the diameter of the earth, and over three times the distance between New York and San Francisco. At the ordinary rate of coal transportation, 54,000,000 tons of coal would make 1,080,000 carloads, 36,000 engine hauls of 150 miles each, and require the use of 5000 railway men, to say nothing of the labor of 70,000 men used to mine the coal, and 80,000 other employees who would automatically be released for other uses.

Third, the saving to railroad property of the United States and Canada. A careful study of reliable statistics shows that every new hydroelectric horse power installed automatically releases something over $100 worth of coal carrying railway property for other general uses. The substitution of 5,400,000 hydroelectric horse power for coal generated power will relieve for other more useful purposes, $540,000,000 of existing railway property in the United States and Canada, and thus relieve the investment field of the need of furnishing this great sum for new railway construction and equipment.

Every well-informed person knows that for many years in the past, the railways in the United States have been handicapped in carrying out needed extensions of all kinds because of lack of funds, and that when our business revives, as we all hope it will some day, the railroads will be behind in capacity to handle freight. Any proposal that will relieve the demand upon railroads (and we of course furnish most of the coal Canada uses) is, as a matter of fact, a blessing to our railroad systems as a physical machine, and therefore, a blessing to the people themselves who in the last analysis really own the railroads. Some people seem to think that the president and board of directors own the railroads. The stockholders own the railroads. When the late James J. Hill died, he owned only 3 per cent of the stock of the Great Northern Railroad, if the newspapers can be believed.

Fourth, the saving in power bills. The construction, and putting to work of 5,400,000 hydroelectric horse power will save power consumers in the United States and Canada at the rate of $35 per horse power per annum, or $189,000,000 per annum, figuring pre-war coal costs which, of course, we all know will never

again be available. This great annual saving in power cost will be a tremendous aid to industry in both countries, that can not be secured in any other possible way.

Fifth, the impetus to new industries by the placing of St. Lawrence power in Eastern Ontario and Western Quebec, New England, and New York, and also along the 354-mile length of the Erie Canal, will create demands for labor and material of great benefit to the

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Figs. 3, 4, 5 and 6 show average ice conditions in the St. Lawrence that navigation and power structures must successfully control. At times more than 675,000 tons of ice per hour will have to be automatically controlled if navigation structures are to continue safe and if power plants are to operate to capacity. The history of eleven power plants at Niagara Falls and on the St. Lawrence, covering approximately fifteen years, shows that in attempting to handle but a small portion of the total ice moving, all but one of these eleven plants, that of the Toronto Power Company, have suffered annually severe ice interruptions to a degree that would seriously interfere with satisfactory long-distance transmission. If power from the St. Lawrence is to be made available for the territory under consideration, the ice problem must be absolutely solved by using the engineering principles that have stood the test at the Toronto Power Company's plant on the Canadian side at Niagara Falls.

public on both sides of the international boundary line.

Sixth, the reconstructed St. Lawrence plus the Niagara power potentialities present and future, will give to the territory extending from Detroit and Windsor on the west, to Quebec and Bangor, Maine, on the east, a continuous power zone in which more than 8,400,000 hydroelectric horse power will be available for industry at practically the same average price on both sides of the line. History does not record a single case in which one of the two bordering countries is continuously prosperous at the expense of the other. The best prosperity is founded always on a full consideration of the "live and let live" policy. The juxtaposition of cheap navigation and cheap power will produce industrial prosperity on both sides of the line which will never be forced to respect, for any great length of time, any international boundary. This prosperity will flow everywhere by the laws of good sense and good economics, as the people are educated up to where they can see the permanent value of genuine reciprocity.

The foregoing six great values are in reality economies with a vengeance, and we should use them before vengeance is upon us for their non-use at a time when economic conditions not only existing, but for decades to come, require our use of every possible economy, if our industries are to survive European and Asiatic competition.

All of these six new great values (and more could be enumerated if time permitted) can be supplied to our people on both sides of the international boundary line without hurting any public or private investment or good purpose, and what is more phenomenal still in the accomplishment of these great results, navigation will not be called upon to sacrifice a fraction of an inch

of navigation depth to water power, and water power will not have to yield a fraction of a horse power to navigation. Surely any set of men who are seriously proposing this great work, and who, with all of the resources of leadership, men, and money at their command, will assume all the risks involved, and will bring about such a consummation in the public interest, deserve and will receive the full support of all of our good people.

How St. Lawrence Benefits Should be Achieved

The question is, how shall this need be supplied, and we are led at once into the age-old controversy of public versus private ownership. The advocates of both of these views are undoubtedly sincere. Twenty years ago before public service commissions had demonstrated their usefulness, too many corporations were guilty of the "public be damned" policy, and the public service commissions were, therefore, the normal result. Thanks to the good work accomplished by these public service commissions the controversy as between public and private ownership is, in my judgment, rapidly coming to a close. The war in a great way demonstrated to us the evils of government management in large affairs. Most of the intelligent people of the United States are now convinced that well regulated private corporations are the best for everybody, as opposed to the inevitable inefficiency that has always been found in government management of business. The history of the Hydro-Electric Commission of Ontario, as it is today being sadly written, is final and convincing proof of the inability of governments to successfully handle great public utilities.

In view of its influence on the whole St. Lawrence situation, I desire to call your attention very briefly to the unusual conditions which have developed in power production at Niagara Falls on the American side. You are aware that in the early nineties when Niagara power first began to take shape, progress in the art of turbine and generator design, together with the scarcity of a reachable market, compelled the use of only a fraction of the total head in the Niagara River. Plants using from 40 to 60 per cent of the total available head were accordingly installed. These fractional heads resulted in the proportionate inefficient use of the water, but it was a case then of inefficiency or nothing. The public everywhere properly acclaimed the courage of these early pioneers in going forth with these new enterprises at a time when so little was known as to what the ultimate destination would be. Hydroelectric engineering all over the world is greatly indebted to the early installations on both sides of the line at Niagara Falls for the experience thus made available in aid of the succeeding advances in hydroelectric engineering. Now, because of great increases in the demand for power, governmental authorities on both sides are requiring that the old diversions at fractional heads should be abandoned, and the water used at maximum efficiency. This requirement has called for the absorption by the new efficient plants of the great sums originally invested in the partial head plants. This union of costs will result in making the present and future cost of generation at the busbars on the American side, between $17 and $19 per horse power, according to the quantity and character of service rendered. On the Canadian side, when the Canadian power plants are compelled to abandon their existing fractional head plants, as they must eventually do in their own interest, their busbar costs will be in excess of $20 per horse power, when all of the charges are in. Any proposals to develop power from the St. Lawrence must take into consideration power prices at Niagara Falls, as to be financed by private capital they must be able to show that St. Lawrence energy compares favorably with Niagara Falls costs, failing in which the project would not attract investment.

The power costs just mentioned bring us now to the all-important question of what percentage of the total cost of the reconstruction of the St. Lawrence River should be charged to power, and what percentage should be charged to navigation. My figures show that according to present day costs of material and labor, and overflowed lands, this ratio should be approximately 75 per cent charged to power, and 25 per cent charged to navigation. If more than 75 per cent is charged to power, the resulting costs will not enable us to compete with Niagara Falls, and thus finance the project. If less than 75 per cent is charged to power, the load on navigation would be more than the traffic can sensibly bear. If the 75-25 ratio is accomplished, it is my opinion that the final cost for energy at generating station busbars will be approximately $17 per horse power exclusive of federal and state taxes. This price of $17 will be guaranteed to the public in advance, and thus save the public from the punishment experienced in the past through overruns in construction costs.

At a juncture when America is in sore need of every economy human ingenuity can devise, is it not most remarkable that we find ourselves, because of many changes in an art not yet forty years old, brought face to face with these unexpected possibilities from the St. Lawrence River?

It is indeed notable that in a stretch of the St. Lawrence River, the average total drop of which is only a foot and seven-tenths to the mile, 5,400,000 horse power can be built which can compete on a par with the greatest water power on the American continent, if not in the world.

We have heard much in recent years about the savings which can be secured to the public by installing great superpower systems, at costs running into the hundreds of millions. These proposals read fairly well, and are attractive to the imagination, and will, I believe, some day be carried out but the raising of these hundreds of millions will be found extraordinarily

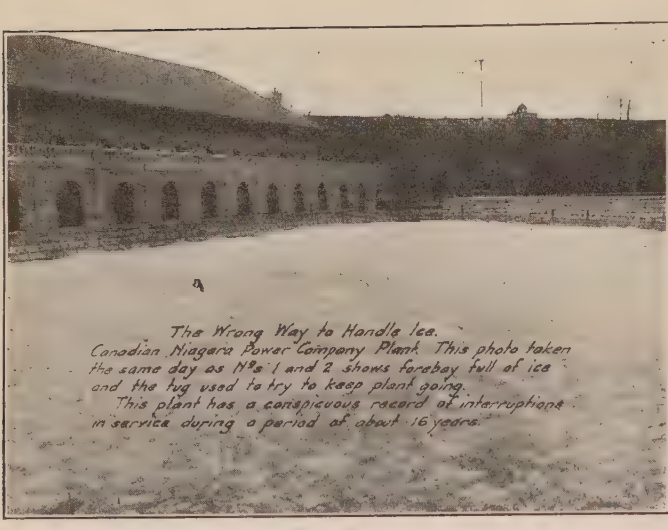


Fig. 7

Figs. 7, 8, 9 and 10 tell their own story. The Toronto Power Company plant is successful and the Canadian Niagara power plant is unsuccessful in handling ice because the Toronto Power Company plant takes its power waters at an angle of 90 degrees with the outside waters that carry the ice, and the attending fact that the average velocities toward the turbines are always less than the velocities carrying the ice. Ice always follows the higher velocity and can not be diverted from the tendency by booms set an appreciable angle from the natural general outside ice direction. Fig. 10 shows the parallel positions of the submerged arches with respect to the ice laden outside waters in the Toronto Power Company plant (called Electrical Development Company on this drawing), and shows the submerged arches of the Canadian Niagara Power Company and their angularity with respect to the ice laden outside water. When the ice is called upon to hit such a submerged boom, as is the case with the Canadian Power Company intake, a sufficient amount of ice passes under the boom to cause the showing in Fig. 7.

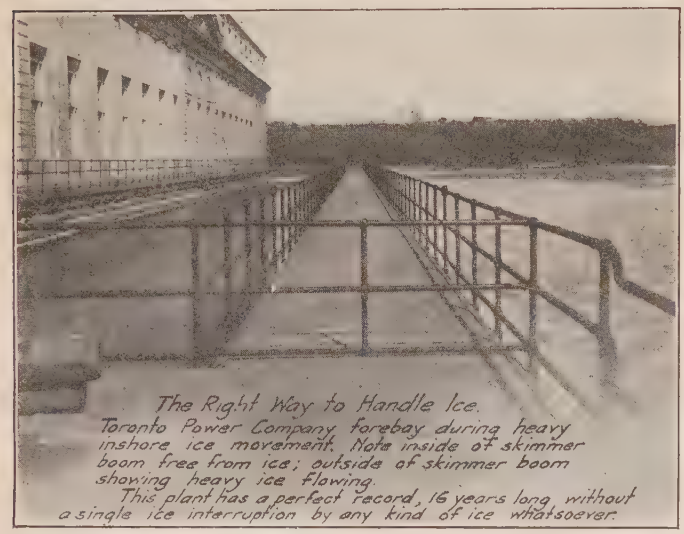


Fig. 8

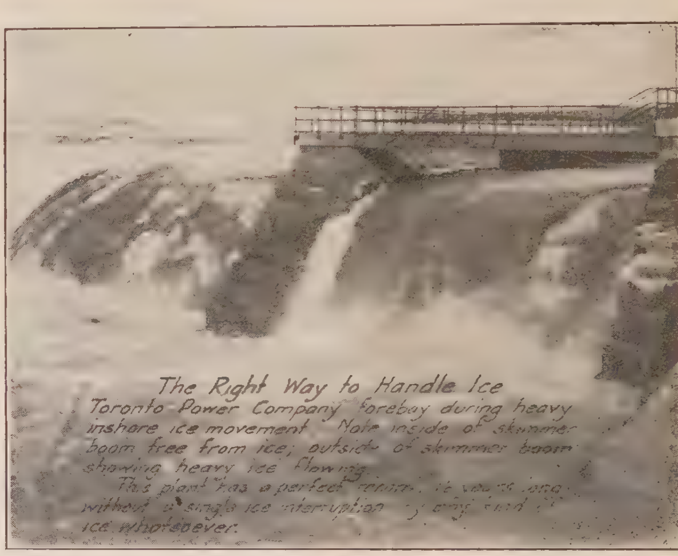


Fig. 9

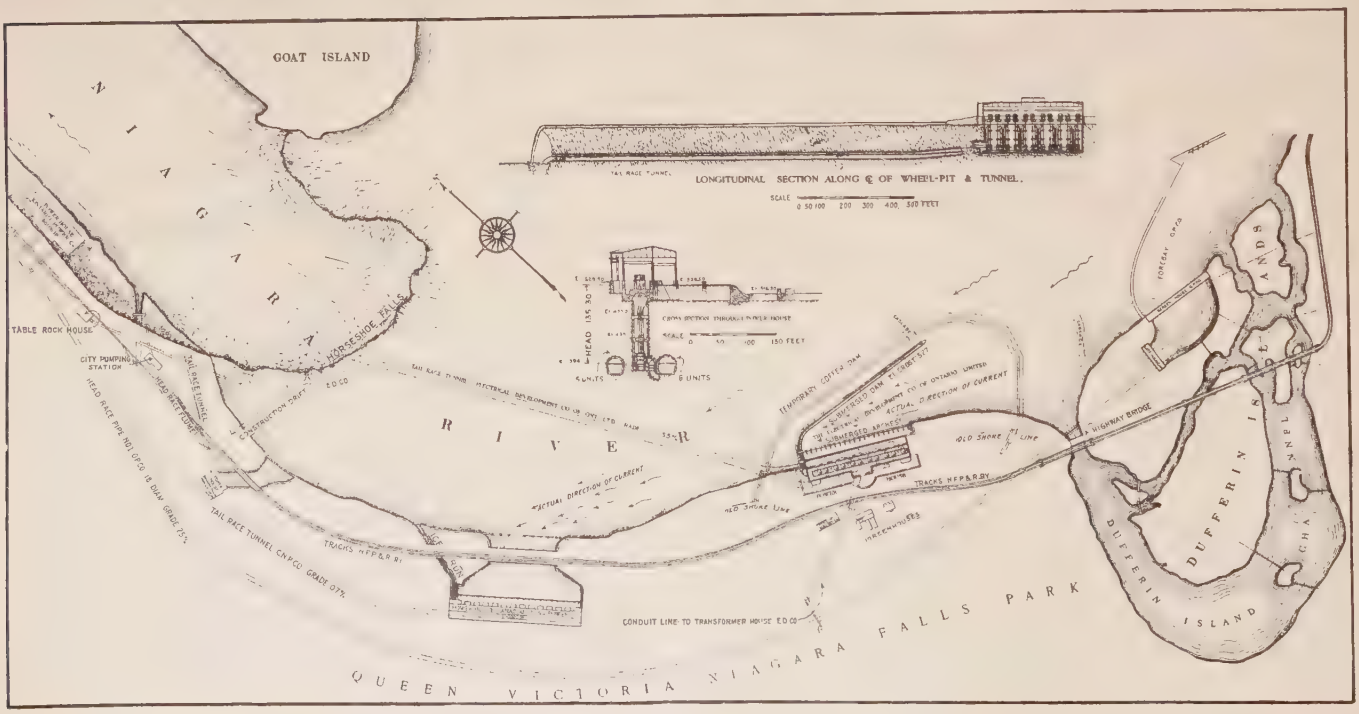


Fig. 10

difficult. The superpower plans will need every big talking point which can honestly be brought to bear upon the subject, and it is my opinion that no great aggregation of money can be secured for steam installations and busbar trunk lines in these new superpower zones until the greater part of the available water power

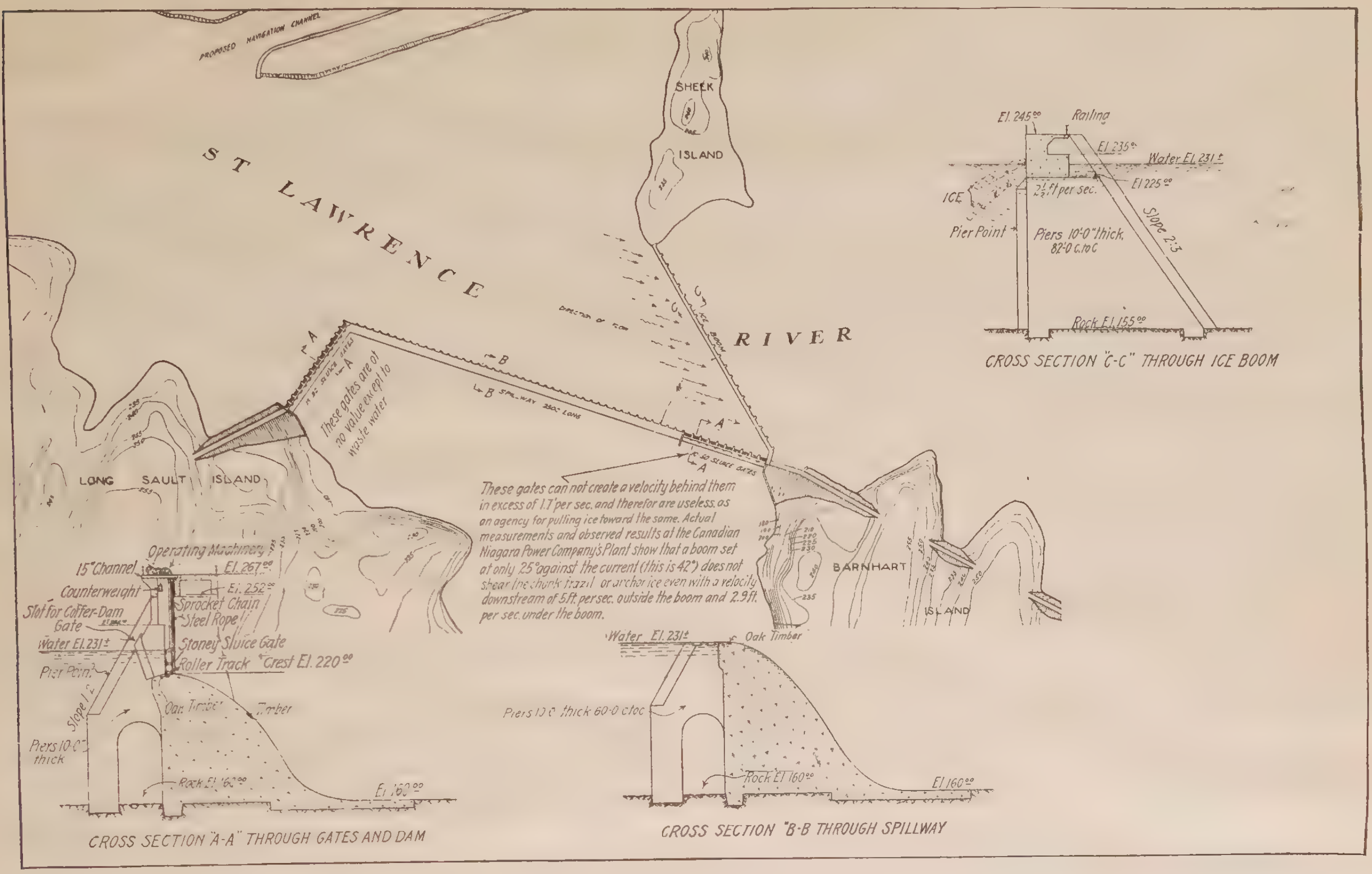


Fig. 11

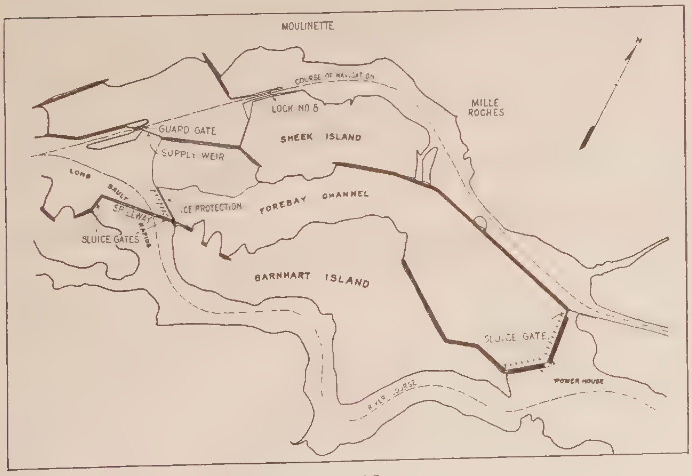


Fig. 12

Figs. 11 and 12 show the manner of handling 675,000 tons of ice per hour recommended by the Wooten-Bowden report. The reasons why this recommended plan would fail are set forth on these drawings. In times of ice movement over 60 per cent of the 1,768,000 horse power would have to be shut down until the ice movement was completed. This shut-down would vary from one day to fifteen days which would be fatal for general power distribution, but would not of course be so serious if the current were used locally for chemistry.

is developed and available as the vertebrae for the superpower zones. Engineers and financiers are not going to assume the responsibilities incident to hundreds of millions in trunk transmission lines and great central stations until the water power competition and capacities are known and ready to become properly the foundation for the big project.

I should like now to give you some very distinct reasons why, in my opinion, the St. Lawrence River must eventually be reconstructed by private capital. My first reason is that governments cannot and private capital can purchase and direct the engineering and construction ability which will be required to reconstruct the St. Lawrence. The engineering and construction ability required for the St. Lawrence work is far greater than that required for any previous construction in the history of engineering. Cofferdams of unprecedented size must be constructed on river beds when more than 200,000 cu. ft. per sec. are flowing, and this quantity of water alone is about five times the maxi-

mum previously achieved. In all previous construction it has been possible to install cofferdams during low periods of flow, but no such low periods exist in the St. Lawrence. As you have seen, ice conditions of extraordinary severity must be overcome through at least four winter seasons for each unit of development. The loss of interest during construction and loading periods will call for unusual progress during the eight or nine months of construction weather. While the Panama Canal cost around $300,000,000 (about twice the official original estimate), this great cost was represented by work which was extraordinarily easy of construction; it was merely a matter of quantity. On the St. Lawrence we have engineering difficulties to which only the tubes under the East and North Rivers in New York are comparable. Speaking of engineering difficulties, it is my opinion, and the opinion of many engineers of my acquaintance, that the greatest engineering work ever accomplished, from the viewpoint of difficulties overcome, was the work of constructing the Pennsylvania Railroad tubes into Manhattan Island and Long Island, and yet I prophesy that when the history of the construction of the St. Lawrence work is written, the consensus of all engineering opinion will be that the St. Lawrence situation presented far more difficult problems than were encountered in the Pennsylvania tubes which I have just mentioned, but would anybody have the temerity to suggest that any government on earth could have carried out the tube construction as it was carried out by the late Alfred Noble and his assistants?

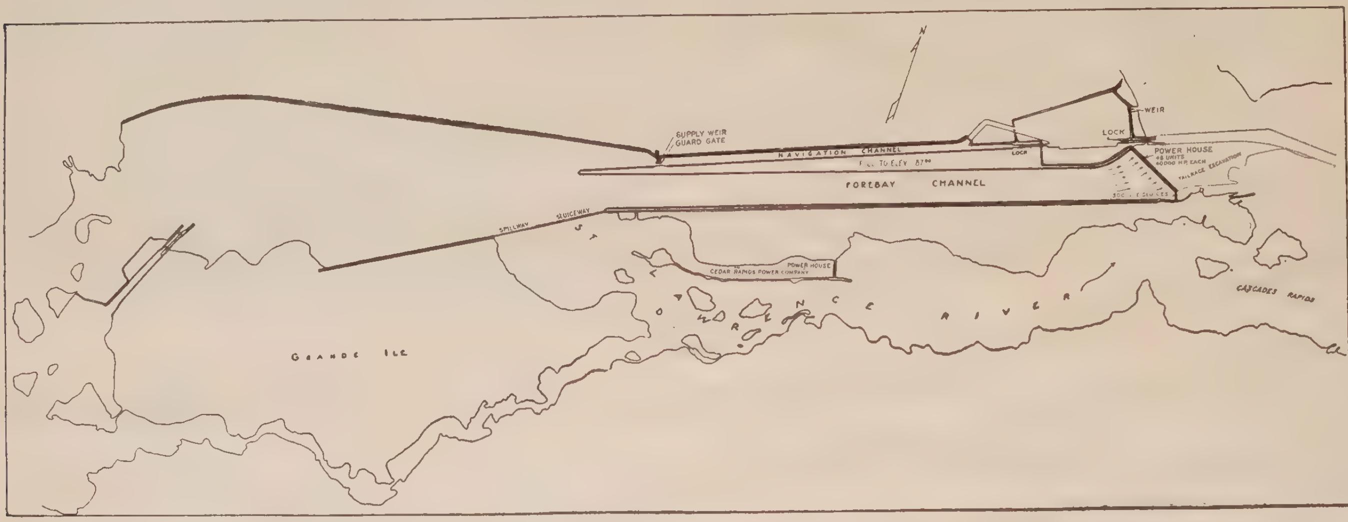


Fig. 13

This shows provisions in the Wooten-Bowden recommendations that are more objectionable even than those shown for the Long Sault plant, Fig. 11. The capacity here proposed for interruption (by even a greater percentage than the 60 per cent at the Long Sault) is 1,920,000 h. p.

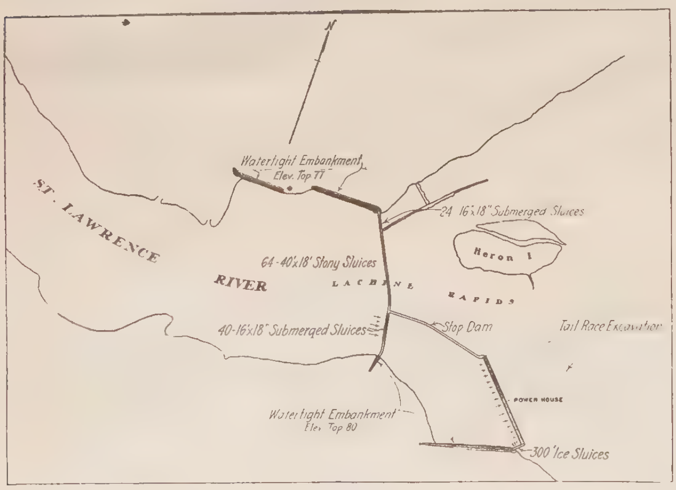


Fig. 14—Proposed Installation at Foot of Lachine Rapids Recommended by Wooten-Bowden Report

Capacity, 787,000 h. p.

Only a small percentage of this plant (not exceeding 15 per cent) could be operated when Lake Ontario and the St. Lawrence River ice is moving out.

The next reason why no government could ever carry out successfully the St. Lawrence work, is the fact that no human direction of day labor has ever been able to cope with governmental red tape, and make government employees really work. It may be claimed by government ownership advocates that the government could contract the St. Lawrence work to regular contractors. My answer to this suggestion is that there are no contractors whose experience would justify their undertaking work of this character and magnitude. The history of the Panama Canal proves this claim, where everyone knows that the contractors fell down. The Panama Canal was carried out by able American engineers from private walks of life, under the able management of General Goethals; but because the difficulties on the St. Lawrence are so much greater than at Panama, the Panama method of construction would fail on the St. Lawrence.

Another great reason why the power side of the St. Lawrence could not be handled by government agencies lies in the fact that coincident with the construction

of the generating stations on the St. Lawrence, there must be constructed vast distributing systems, by private capital, for the use of the energy when it is ready for delivery. The private capital for these distributing systems will not, in my judgment, be found

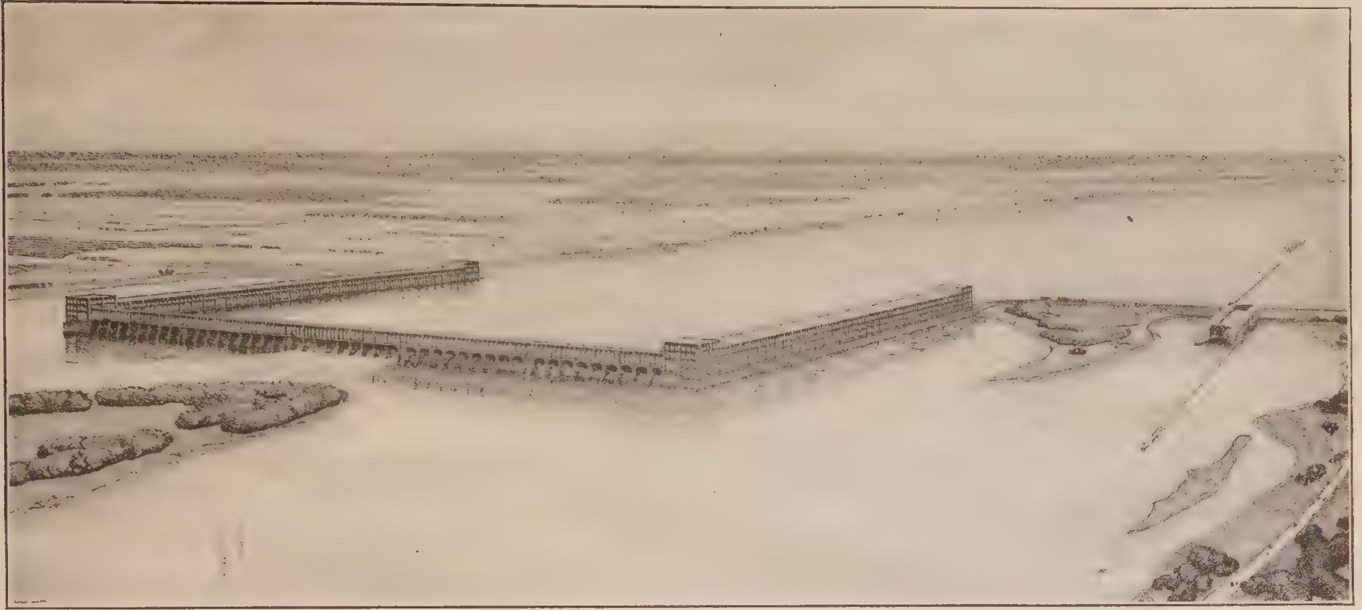


FIG. 15—BIRD'S-EYE VIEW OF THE CAT ISLAND PLANT FOR INSTALLED CAPACITY OF 1,200,000 HORSE POWER

This view is a true perspective from the Canadian shore made from a complete set of borings in the bed of the river, from a complete set of mechanical drawings and from a complete set of topographical maps costing altogether in excess of $200,000.

willing to undertake the financing of distributing systems that are to receive their current at some unknown time when government agencies could complete the work, if they could complete it at all. If the St. Lawrence power development is made by private capital it will be entirely practical and feasible for distributing companies to make private contracts with generating stations, which contracts, being approved by the public service commissions, and enforcible by law, will therefore be proper foundation for distributing system financing. If governments should undertake the construction of the power work in the St. Lawrence, the only way distributing companies could operate would be to wait some indefinite time until the power plants were completed, and such a wait would entail, of course, vast losses of interest.

As to building the locks, this work will have to be in the hands of private management, because the very nature of the work would prohibit the use of two organizations trying to manipulate heavy construction at the same time and place. While the locks and their appurtenant works will have to be paid for and operated by the governments, their construction by the organization which builds the power works can be arranged for on terms advantageous to the governments.

I have briefly enumerated a few of the major benefits that will result from a reconstruction of the St. Lawrence River. We are all in accord as to the value to the public of this greatest of our undeveloped resources, and of the urgency of our need of these resources. The St. Lawrence River and its Great Lakes basin have been under active official study and survey for over one hundred years, with the result that no other region of our Continent is so fully covered by general engineering reports. Of course we could go on discussing and reporting on this subject for another hundred years. What we need now is to begin physical work as soon as

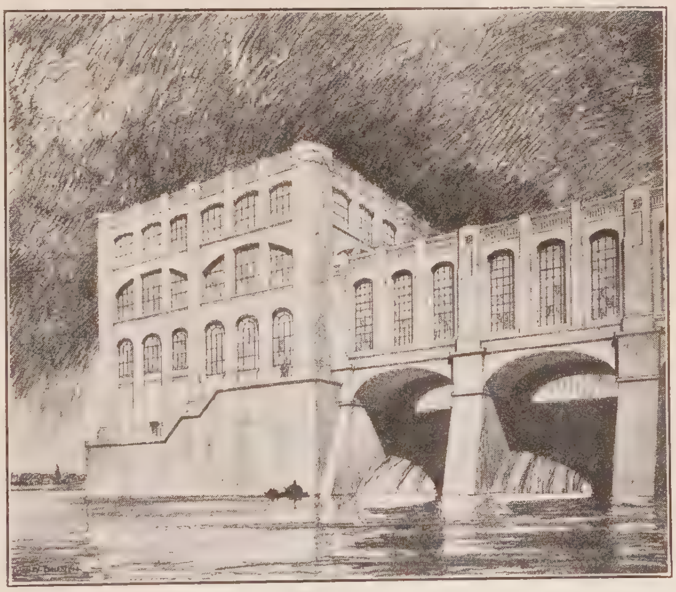


FIG. 16

Close-up perspective drawing showing two of the eighteen feet deep control gates, their gate-house superstructure and its connection to the downstream end of either the Canadian or the American power house.

the best plans can be adopted. The outstanding need in American industry today is relief from present excessive federal taxation. Until this relief is felt the

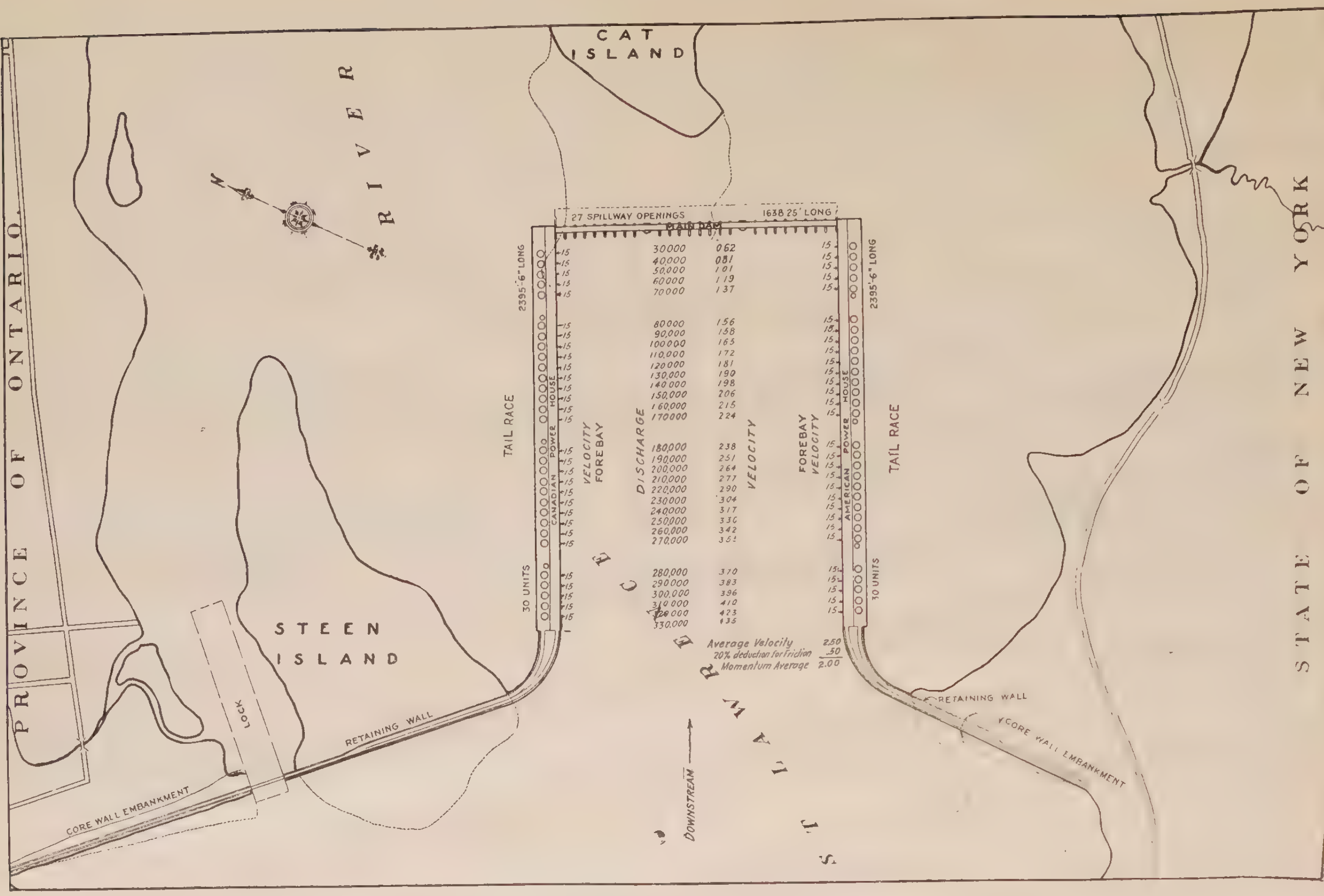


Fig. 17—Dam No. 1 at Cat Island

No diversion of approaching ice from its natural direction for two miles above the control dam is required. It is disposed of through the main dam without the diversions previous experience shows conclusively must be avoided. The average velocity toward the dam is 33 1/3 per cent more than the velocity of the power waters to the wheels. This arrangement, as will be readily seen, calls for a great increase in the cost of the work because of a heavy increase in all cubitures of masonry, cofferdams and excavations. The project must stand these extra costs necessary for 100 per cent reliability or remain unconstructed. The incomplete but fairly satisfactory data in hand show that the general arrangement recommended by the Cooper plans for the Cat Island development can be installed with but little modification at Dams 2, 3, 4 and 5.

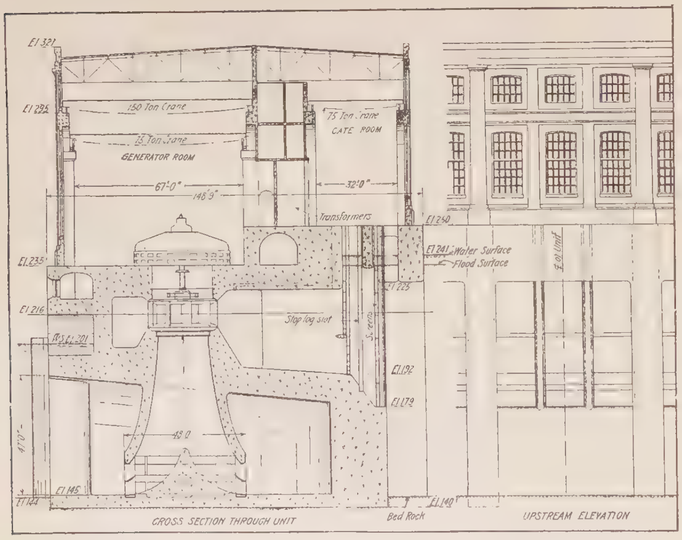


Fig. 18—Cross-Section of the Cat Island Power House Showing a Main Generator 20,000-H. P. Unit

It will be observed that this work is standard except for the depth to foundations which is about 65 feet.

cost of living will be high, and labor and capital both must suffer. To hope that the Federal Treasury at Washington can supply for many years to come, the hundreds of millions needed for this enterprise as a governmental measure, even if its feasibility as such were unquestioned, is hoping for the unreasonable and impossible, and what of Canada and her half of the costs as a governmental measure? Canada has 9,000,000 splendid people who are today struggling with a per capita debt nearly twice our per capita debt, incurred through her wonderful loyalty to the mother country. Her casualties were 800 per cent per capita greater than ours. Canada is today struggling with an annual deficit of more than $60,000,000 in government owned and operated railroads. She must bear the burdens incident to an oversupply of hydroelectric power in Ontario, the cost of which is unnecessarily high by many millions and she has many other problems of a financial and social character, all of which she will solve in due time with great credit to herself. Because of all of the foregoing every sane, thoughtful Canadian knows that Canada cannot take on her share of the cost of the new St. Lawrence as a governmental venture for decades to come.

No, the government ownership program is not the way forward. The way forward is through encouraging private capital, properly regulated, to take up the rebuilding of the St. Lawrence along the lines the Federal Congress and the State of New York have laid out for private capital after more than ten years of continuous study of the navigation and power questions as applied to our navigable streams. I am of the opinion that the Federal and State Water Power laws provide the safest and most expeditious plan of procedure for the achievement of the new St. Lawrence. In these laws, the public interest is most fully protected. They give private initiative the fullest competitive opportunity, and thus provide maximum efficiency. If the Commissions, Federal and State, will issue the necessary St. Lawrence permits, and if Canada does her part, as I am sure she will, and finally and most important, if Canada and the United States will provide at once a high-grade permanent commission of engineers to approve the plans that are agreed upon under the operation of the permits, and to supervise construction when licenses are issued, then we will safely and speedily bid good-by to the "talk" zone, and go hopefully and confidently forward into the "work" zone of this great endeavor. No other plan, it seems to me, will ever get us anywhere for years and years to come, and if the plan I have recommended is safe and sane, why don't we get together, and pull together, and always pull in the same direction?

In conclusion I desire to thank you heartily for the close attention you have given this very brief address on what I know you will agree is a subject that will be in the minds of all of us for many years to come. I will have no pride of opinion on this subject as and when better views are advanced. The St. Lawrence enterprise is too important in its wide influence upon millions of our people to allow any mistake to be made. Its early consummation requires only the elimination of a small amount of public and private misinformation regarding it, and I predict this elimination will be accomplished much sooner than most people think.

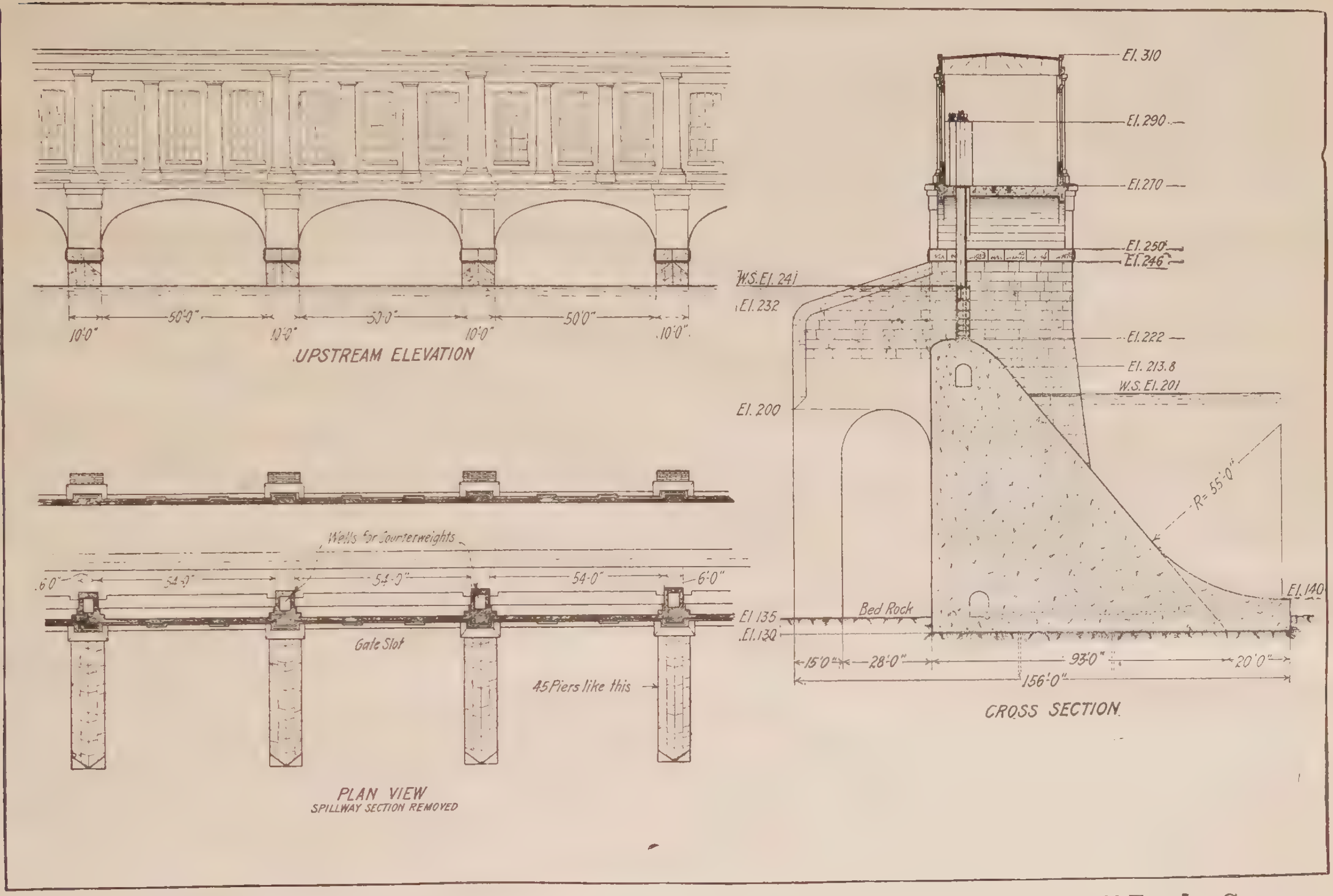


Fig. 19—Cross-Section Through the Main Dam Showing Ice Breakers 10 Feet Thick Spaced 60 Feet on Centers

Note that the large cakes of field ice approaching these ice breakers will be forced to ride up the sloping noses of the ice breakers in the usual way and thus be broken into fragments for passage through the open channels 18 feet deep immediately below the breakers, and then safely over the spillway to the pool below, from which pool the ice will be cleared by repetitions of the same process until all structures are safe. The plans here recommended will enable such a control of the St. Lawrence ice through the use of stored water from Lake Ontario as will also guarantee the City of Montreal complete immunity from the frequent ice troubles that have occurred in the past.

The St. Lawrence Project

BY H. I. HARRIMAN

of Chase & Harriman, Inc., Boston, Mass.

THE great channels of trade in North America run east and west. The great river systems of the continent run north and south. There is, however, one striking exception to this general rule, where the course of the Great Lakes and the St. Lawrence breaks through the Appalachian Range, and forms a continuous waterway, 2000 miles in length, from the center of the continent to the Atlantic Ocean. Much of this water course is now open to navigation and the American Great Lakes have within the last twenty years witnessed the most remarkable maritime developments of any section in the world. The Lakes extend approximately 1000 miles from Duluth or Chicago to Buffalo through the very heart of America; and within the last two decades there has grown up on these Lakes a traffic whose tonnage exceeds that of the Mediterranean and the Black Sea combined; indeed the movement of vessels through the locks between Lake Superior and Lake Huron is twice the combined movement of vessels through the Suez and Panama Canals, and more tonnage passes Detroit in nine months than clears from New York or Liverpool in a year. Along or near these Great Lakes lives approximately forty per cent of the population of the United States. Not only are the shores of the Lakes thickly populated, but the territory contiguous to them is rich in agriculture and in mineral products. Wheat, grain, livestock, iron, coal and copper are among the great inheritance of this rich fertile region of our country. This region has also become a great manufacturing center. Flour, foodstuffs, packing products, automobiles, rails and other heavy steel products, and many other articles of commerce are produced in this region; and these articles, as well as the products of the soil and the mines, flow eastward over the waters of the Great Lakes until the port of Buffalo is reached, where they must be transferred to the rails, and move the last 500 miles of their journey to the seaboard by car rather than by boat.

Between the eastern end of Lake Erie and sea level in the St. Lawrence River, a distance of 400 miles, there are two natural obstacles which prevent navigation: first, the falls of the Niagara River; and second, the rapids of the St. Lawrence. There have for many years been shallow canals and locks around both of these obstacles, but they have accommodated vessels of such small size as to be of practically no value to commerce. In view of all these facts, it is not surprising that the people of the Middle West living near the Lakes are asking that these obstacles to commerce be removed, and that the ships of the Great Lakes be permitted to pass freely around Niagara and down the St. Lawrence to the ocean. Already the Canadian Government has undertaken the construction of an enlarged Welland Canal around Niagara Falls at the cost of about $80,000,000. This canal will, when completed, accommodate the largest lake vessel, having a capacity of approximately 15,000 dead-weight tons, or 500,000 bushels of grain. The locks of the canal will be 800 feet by 80 feet by 30 feet. The canal will initially be dredged to a depth of 25 feet, but can at any time be deepened to the full 30 feet permitted by the locks. Work on the enlarged Welland Canal has made considerable progress, and the canal should be ready for use during the year 1925.

The Welland Canal will, however, be of little use until the St. Lawrence River is made navigable to the sea. Accordingly it is proposed to drown out the upper rapids of the St. Lawrence by means of a large dam with locks, erected near Cornwall, and to parallel the two lower rapids with two canals and their locks, the canals aggregating about 33 miles in length. By means of these structures a 25-foot navigable waterway will be created from Lake Ontario to the sea. The locks of this project are to have a depth of 30 feet over the sills so that by additional dredging in the canals a continuous depth of 30 feet can be established. When this project is carried through, the largest lake vessels, some of which carry as much as 14,000 tons dead weight, can proceed to tidewater at either Montreal, Quebec or Halifax, where transfers of freight can be made to ocean vessels. It will also be possible for any ocean vessels drawing not more than 25 feet, and ultimately 30 feet, to enter the Great Lakes. More than 200,000,000 tons of freight now move each year east and west between the territory contiguous to the Great Lakes and the Atlantic seaboard. Much of this traffic always will be carried by the railroads of the country, but when the St. Lawrence Project is completed a material portion of this hugh volume of traffic will undoubtedly seek the water channel. This is conclusively proved by the tremendous growth of traffic upon the Great Lakes, which now exceeds 100,000,000 tons annually.

The opponents of the St. Lawrence Project have laid much stress upon the fact that the present channels and ports of the Great Lakes will accommodate only vessels with a draft of twenty feet or less; and that for that reason large ocean vessels cannot ply the Great Lakes until huge additional expenditures have been made upon their channels and harbors. The argument seems immaterial. As previously stated, all types of lake vessels can proceed to tidewater and there discharge their cargoes into ocean-going vessels, and there will be but one transfer and no rail haul, instead of two transfers and a rail haul as at present. If, however, there is a demand for through traffic between lake ports and foreign countries, it is entirely feasible

Address delivered at the Spring Convention of the A. I. E. E., Chicago, Ill., April 21, 1922.

to construct ocean-going vessels of 8000-10,000—or even 12,000 tons burden of present lake draft. Such vessels of 10,000 tons burden are now in use carrying ore between Cuban ports and the Chesapeake Bay; and if the St. Lawrence Project is carried to completion, there is no question that our maritime engineers, who have so successfully designed vessels for the lake trade can also design a vessel of any desired size to ply between lake ports and ocean ports as they now exist.

The opponents of the Project have also based their opposition upon the alleged dangers of narrow and tortuous channels, of fogs and ice, and of seven-month limitation upon the use of the waterway. The St. Lawrence River will be made navigable by the construction of a large dam at the lower end of the International Section, and by two canals around the two sections of rapids that lie entirely within Canada. In the entire length of the St. Lawrence there will be but nine locks and thirty-three miles of canal navigation. For the balance of the distance navigation will be through a river as wide as the Hudson at New York City; and the entire delay incident to canal navigation in the St. Lawrence and in the Welland Canal will be less than the time required by an ordinary freighter to travel 200 miles. Fogs exist in the lower St. Lawrence; but the hydro-graphic charts of the Federal Government indicate that the fog belt between Montreal and Liverpool is of less extent than between New York and the same port. Fogs and ice have not prevented Montreal from becoming the second port of export in North America; nor has the closure during the winter season stopped navigation upon the Great Lakes or prevented the construction of the Erie Canal.

For these reasons I believe that with the opening of the St. Lawrence to navigation the Middle West will have a usable water route to tidewater over which freight can be sent at much less expense than over all-rail, or water-rail, routes now in existence. I further believe that the existence of such a water route will affect not only the rates of the grain and other freight which actually use it, but the whole rail rate structure between the Middle West and the Atlantic seaboard. This has certainly been the effect of the Panama Canal upon rail rates between Atlantic and Pacific ports.

The extent of the saving arising from water transportation cannot be definitely prophesied, but reasonably accurate conclusions can be drawn from existing rates. At present a bushel of wheat is carried from either Chicago or Duluth, 1000 miles to Buffalo, for 2 cents or less; and on the same mileage basis, with due allowance for delays in canals and locks 3 or 3½ cents would be a fair rate to Montreal. The lowest rate at which grain can now be carried from the West to tidewater is 2 cents to Buffalo, and 12 cents from Buffalo to New York or Boston—a total of 14 cents. This shows a saving to tidewater of at least 10 cents per bushel *via* the St. Lawrence route; and as New York and Montreal are equally distant from Liverpool, it would mean an equal saving on the through rate. What holds true of grain will also hold true of many other western products destined for European ports.

I also believe the St. Lawrence route will favorably affect the transportation costs between the Middle West and the Atlantic Coast ports. The rail rate for the entire country is now approximately 12.1 mills per ton-mile. If coal is excluded this average rate rises to 15 mills. Water rates on the Great Lakes average less than 1 mill per ton-mile; and on the ocean vary according to the class of freight from 1 to 3 mills. Probably 2 mills per ton-mile is a fair water rate to compare with an average rail rate of 15 mills.

From Chicago to Boston the rail distance is 1034 miles as against 2682 by water. From Duluth the relative distances are 1513 as against 2775; and taking into account relative rail and water rates and relative distances, it would seem that a ton of freight is now hauled by rail from Chicago to Boston for $15.51, as against an estimated charge of $5.36 by the water route. The corresponding rail rate for Duluth is $22.70 as against an estimated cost of $5.55 by water.

Figures based on averages may not be exact, but they do indicate tendencies; and they certainly give assurances that freight can be carried from the Middle West to Atlantic ports by water much cheaper than by rail.

It is a well recognized economic principle that the price of any commodity in universal use is determined by the price at which the surplus of that product must be sold. The surplus grain of the world is sold in Liverpool. To this market is shipped the surplus grain from the United States, Canada, Argentine, Russia, and Australia; and there in competition the world price of grain is established, this price governing not only the grain sold in the Liverpool market but the grain sold in the producing countries. The price in the producing country is therefore the world price set in the Liverpool market less the cost of transportation between the farm and the English Channel; and the American farmer receives each year for his grain the Liverpool price less the freight to Liverpool. If therefore, it is possible to reduce the freight charge by 10 cents per bushel, the farmer will receive 10 cents per bushel more for his entire crop. This would mean over $350,000,000 per year to the farmers of the country. Every other grain producing region of the world which has a surplus lies within 250 miles of navigation. Our grain region lies from 1000 to 1200 miles from the coast; and this great handicap upon our western farmers is the great reason for their insistence to (use the words of the President) that "the salted and unsalted seas be connected by a suitable channel."

By act of the American and Canadian Governments, a Joint Commission of the two nations has been in-

vestigating the feasibility and cost of the project. This Commission has recently submitted its report to the two Governments, and its findings are that the project is feasible, desirable, and reasonable in cost. The estimates of cost were made by Government engineers of the two nations after an examination extending over a year's period. These engineers estimate the cost of the entire project at $252,000,000, this estimate including the cost of producing 1,464,000 horse power of continuous energy. The figures were based upon 1920 costs—as an example, concrete is estimated at $12.00 per yard. It is further the express belief of the engineers that the figures of cost are conservative and that due allowance has been made for the inevitable contingencies of a project of this size.

Mr. Hugh Cooper, an eminent hydraulic engineer, who has made extensive studies of the St. Lawrence River, believes that the plan proposed by the Government engineers is impracticable, that their estimates of cost are inadequate, and that their scheme is wasteful of the potential energy of the stream. Cooper proposes a different plan which, at a cost of about $300,000,000 for the International section, will make that section navigable and develop about 2,400,000 horse power. To this $300,000,000 must be added about $100,000,000 for the canals around the lower rapids, in order to make the entire river navigable. The total cost of his project is therefore approximately $400,000,000 as against $252,000,000 for the plan of the Government engineers.

The criticisms of Mr. Cooper should be given most careful consideration in the preparation of the final plans. In my opinion, however, the vital fact is that both the Government engineers and Mr. Cooper agree that it is entirely feasible to improve and make navigable the St. Lawrence River, and to develop as an adjunct thereto a huge block of reliable electric energy; and while Cooper's estimates are higher than the estimates of the Government engineers, yet the amount of power which he will develop is far greater and there is really very little difference in the cost of a horse power as developed by one or the other plan.

The value of the power which will be produced on the International section will largely offset the annual cost of the project. Based upon a cost of $252,000,000 the interest charges, sinking fund requirements, and operating expenses of the project, if carried through by the Government, should not exceed $17,000,000 per annum. If the entire annual cost of the project is charged against the power development (and I do not advocate this) it means an annual switchboard cost of from $11.00 to $12.00 per horse power. This is equivalent to a kilowatt hour cost of from 2 to 4 mills depending upon the load factor at which the energy is taken. To this switchboard charge must be added the transmission costs from the St. Lawrence River to the great markets of New England and New York; but after making such allowance it is certain that, according to either plan, energy can be laid down at great central substations in New England and New York at well under 10 mills per kilowatt-hour.

I do not feel that the entire cost of the project should be charged against power. The figures cited are however based upon the entire charge of the project being carried by the power developed; but it may well be argued that navigation should pay a portion of the cost, thus enabling power to be sold at lower rates than above indicated. I, however, wish to point out that the market is ample to absorb all of the power which can be generated; and that the energy will be exceedingly cheap even if power carries all of the charges. Within a reasonable time after the St. Lawrence is open to navigation, it can be made a self-supporting project, and would be well warranted merely as a plan for the development of energy.

The Western proponents of the Great Lakes project have assumed that the project would be carried through in its entirety by the Governments of the two nations, and I have thus far discussed the proposition from that standpoint. A statement, has however, recently been made by gentlemen connected with large financial interests that a group of American financiers are prepared to construct two dams along the International section which would develop nearly 2,000,000 h. p., and whose construction would also drown out the rapids of the international section of the river and by the construction of locks in the two dams (to be paid for by the two Governments) make the river navigable from Lake Ontario to Lake St. Francis.

If such an arrangement can be worked out, it should be given most careful consideration, as the task left to the two governments would be merely the construction of the lower canals with their locks. Under such a plan the government expenditures would probably be less than $100,000,000. Furthermore, it would remove the governments from any connection with the development of hydroelectric energy and leave that business to private enterprise,—a most desirable outcome, if feasible.

My own feeling is that the two great features of the project—continuous navigation from the Great Lakes to the sea, and cheap hydroelectric power—must both be carried out. No plan must be adopted which gives one without the other, or which delays one at the expense of the other. With these fundamental facts in view the more that can be done by private enterprise and the less by the two Governments, the better it is.

Some opponents of the project claim that it will work great injury to the railroads of the country, and tend to increase existing freight rates. Such opponents fail to take into account the tremendous growth of the traffic of the nation. In 1890 the railroad tonnage of the country amounted to 79,000,000,000 ton-miles; in 1900 it had risen to 141,000,000,000 ton-miles; by

1905 it had increased to 187,000,000,000; and in 1921 exceeded 448,000,000,000 ton-miles. This shows a steady increase of approximately 100% in each decade; and would indicate a tonnage of 800,000,000,000 ton-miles by the time the St. Lawrence project becomes an actuality. I remember the frightful congestion of traffic in 1918, and am appalled at considering the expenditures which must be made to handle the inevitable traffic of 1930. At present the population tributary to the Great Lakes is 40,000,000. Twenty-five years from now it may well be 75,000,000; and the requirements of the growing traffic of the country, and of its growing population will demand the use of every possible avenue of transportation. I therefore feel that the development of water transportation from the center of the continent to seaboard will be of immense advantage to the railroads, greatly reducing the investments they must make, and enabling their existing rails to be used for local and high-class tonnage. The following quotations from a recent address of Mr. Elisha Lee, Vice-President of the Pennsylvania Railroad, are of great interest. He says:

> Traffic on our American railroads measured in ton-miles doubles about once in a decade. This rate of increase has been maintained for at least two generations with surprising regularity, despite the varying cycles of booms, panics and depressions through which the country has passed meanwhile.
>
> The next time our country has a real revival of business we shall in all probability be confronted with the most severe congestion of railroad traffic, and the greatest inadequacy of railroad facilities, ever experienced in our history. When that happens rates will be lost sight of. Every one will be clamoring for service. Nothing could more quickly check a wave of prosperity than the inability of our railroad facilities to handle the traffic which good times will create.
>
> I am firmly convinced that we face such a condition with almost absolute certainty in the not remote future.

One more objection remains to be considered, namely; the sentimental objection of the investment of American money in Canadian territory. In this connection, however, it should be remembered that by treaty the Great Lakes and the St. Lawrence for their entire length are open to the equal use of the nationals of both countries. Since the war of 1812 the lakes and the river have been recognized as the joint artery of the two governments. Our use of the St. Lawrence because of our greater population, and industry, will greatly exceed the use of Canada; and there is certainly no sound reason why we should not bear our proportion of the expense irrespective of its location. It should be noted further that each nation is to pay the entire expense of its own power developments; and that expenses are shared only as they refer to navigation. Canada owns the Grand Trunk Railroad, and thus has an investment in the United States of over $200,000,000 and if Canada has not hestitated to invest in railroads partially within the United States, certainly we should not hesitate to invest in a joint waterway more beneficial to us than to our neighbor. If the United States and Canada jointly develop this great route of trade, it will tend to cement the ties of industrial and political friendship which have existed between the two countries for over a century.

Thus far I have considered the St. Lawrence Project from its effect upon the nation as a whole; and my conclusions are that it will greatly benefit the commerce and industry of the country.

Let us turn now to the consideration of the immediate effect of the project upon our own state and upon the Port of Boston. Commercially, it will give us a direct water route between the Middle West and our own ports. It will also bring lake traffic to the terminals of our New England railroads at Ogdensburg and Montreal, and thus reduce the distance to lake navigation from 500 miles at Buffalo to 250 miles at the St. Lawrence. Our traffic will also be free from the crowded gateways at Albany and Buffalo; and our own railroads through their own or affiliated boat lines will reach all of the great ports of the West. The existence of such a route will also help us to maintain our present differential rates which have been so great an asset to New England's industries. Finally, it will give us a definite and compelling reason for the abolition of the rail differential which now exists in favor of Philadelphia and Baltimore.

The project will also give to New England a supply of cheap energy nearly sufficient to operate its railroads, its utilities, and its industries. Previously in this report we have discussed the cost of power generated on the St. Lawrence. Suffice it to repeat at this time that power can be generated on the St. Lawrence and transmitted throughout New England at a cost less than the cost of power made by coal at the mouth of the mine in Pennsylvania. Not least among the advantages of the hydroelectric power of the St. Lawrence is the fact that it will tend to grow cheaper with increased use, whereas power generated by coal is bound to increase in cost with the growing scarcity of fuel. Finally, our power supply will be free from the embargo and the delay at the crowded railroad gateway. The industry of New England needs for its continued maintenance and prosperity efficient and cheap transportation and low-priced power. Both of these will be supplied when the St. Lawrence is open to navigation and its power made available for use.

New England's chief argument against the opening of the St. Lawrence has been its fear that the foreign commerce of the Port of Boston would be seriously affected. This objection is worthy of every consideration. No positive prediction can be made as to the beneficial or harmful effect on Boston's foreign commerce. The arguments which have been presented show great possibilities for good as well as harm. Boston's foreign commerce has for the last twenty years steadily declined, until it has reached the lowest point in its history. This has been due largely to the operation of the rail differentials in favor of South Atlantic Ports, which have diverted from Boston the

grain and other heavy commodities required in a properly balanced cargo. Last year Boston's exports of grain were only about 4,000,000 bushels out of a total of 300,000,000 for the entire country and Canada. If the St. Lawrence route is opened, much grain will be brought to river ports in lake vessels and stored in elevators for export purposes. Much of this grain will go abroad directly by water from Montreal; but it is also true that much of the stored grain will come to Boston and Portland, particularly during the five months when the St. Lawrence is closed, and thus fur-furnish Boston the bulk cargo which her foreign commerce requires. It must also be of great advantage to New England ports to have the tonnage of the Great Lakes brought within 250 miles of its ports and in direct touch with its own rail heads on the St. Lawrence; and New England's railroads whose interests are identical with the interests of the Port of Boston, will have every incentive to make rates which will bring the lake commerce to Boston. Mr. A. H. Ritter, of the Department of Commerce, has very clearly brought out the fact that Boston has a large inbound commerce, and is particularly in need of export products, in order that ships may have both inward and outward cargoes. He also points out that Montreal has very little inbound commerce, and that a vessel could better afford to come loaded to Boston and pay the rail haul from Ogdensburg or Montreal to Boston for export cargoes, rather than to go to Montreal empty and effect the saving of the rail haul.

It should also be remembered that the value of any port is measured by its service to domestic as well as foreign commerce, and no one can doubt that a large amount of domestic commerce will flow by water from the Port of Boston to the ports of the Great Lakes. While, therefore, there is a possibility that some of the commerce of the West now flowing through New York and Boston will flow directly to Europe via the St. Lawrence, yet, so far as Boston is concerned, there is every probability that through this route she will gain the bulk cargo, at least during the winter season, which her foreign commerce now lacks.

Various other local objections have been raised. For instance, Montreal fears that freight will pass by it and that it will become a way-station on the St. Lawrence. Portland is apprehensive lest it lose some of the grain which the Grand Trunk now ships through that harbor when the St. Lawrence is closed. Buffalo fears that it will lose the transfer charges now paid at that port; and New York State fears that the Erie Canal will receive less traffic.

All of these local objections must be given due consideration. I think, however, it can be assumed that no local consideration should stand in the way of a great economic development which will benefit much of the country; and Montreal, Portland, Buffalo, or New York cannot permanently expect to receive a toll for their individual benefit that increases the cost of moving the exports or imports of the world to and from the West, or that denies to New England a much needed supply of cheap power. The weavers of Lancashire objected to the introduction of the power loom because they feared it would deprive them of their livelihood, but the power loom made Manchester. So these local losses will be more than made up by resulting benefits which cannot now be foreseen.

In my opinion, New England and New York have more to gain from this project than even the States of the West which are now so actively supporting it. When men like President Harding and Secretary Hoover advocate this project as one of the greatest constructive engineering projects of this generation, and say it is a development equal in its importance to the Suez or Panama Canals, all must admit that it is of great national, as well as local significance.

The people living in the region of the Great Lakes are in the same position as the people residing along the shores of the Mediterranean would be if the Straits of Gibraltar were closed, or the nations bordering upon the Black Sea if the Dardanelles were obstructed by impassable rapids.

At present the great demand for the improvement of the St. Lawrence comes from the merchant, the manufacturer, and the farmer of the Middle West and the Northwest, and from Canada, who demand that the traffic of the Great Lakes have direct access to the sea; but when the citizens of New England and New York appreciate what the project really means to their industries and to their railroads, they will be equally insistent that the St. Lawrence be opened to world commerce and its power made available for the use of mankind.

I cannot better close than by quoting the words of President Harding in his address to the National Agricultural conference held in Washington on January 23d. He said:

> I have spoken of the advantage which Europe enjoys because of its easy access to the sea, the cheapest and surest transportation facility. In our own country is presented one of the world's most attractive opportunities for extension of the seaways many hundred miles inland. The heart of the continent, with its vast resources in both agriculture and industry, would be brought in communication with all the ocean routes by the execution of the St. Lawrence waterway project. To enable ocean-going vessels to have access to all the ports of the Great Lakes would have a most stimulating effect upon the industrial life of the continent's interior. The feasibility of the project is unquestioned, and its cost, compared with some other great engineering works would be small. Disorganized and prostrate, the nations of central Europe are even now setting their hands to the development of a great continental waterway, which, connecting the Rhine and Danube, will bring water transportation from the Black to the North Sea, from Mediterranean to Baltic. If nationalist prejudices and economic difficulties can be overcome by Europe, they certainly should not be formidable obstacles to an achievement, less expensive, and giving promise of yet greater advantages to the peoples of North America. Not only would the cost of transportation be greatly reduced, but a vast population would be brought overnight into immediate touch with the markets of the entire world.

Anothor View of the St. Lawrence Project

BY S. WALLACE DEMPSEY

House of Representatives, Washington, D. C. Chairman of the Committee on Rivers and Harbors

THE question as to whether the United States shall help Canada defray the expense of improving the St. Lawrence river, as Mr. Cooper said, is a great question. It is one that involves an enormous amount of money and it would take, the engineers estimate, at least ten years to do the work. So we should know well before we begin what the problem is, what it promises, how it compares with other things. It is a great transportation problem. Primarily at the base of it is the question of transportation. Water power is purely incidental.

I am to talk to you as to how this question presents itself from the standpoint of the United States. Well, we are just at the end of a great war. For the first time in the history of the country we are groaning under the burden of an enormous debt. Every question of Government activity has to be met from that angle and I am going to illustrate it to you. The city of Chicago has furnished a very able man as the first director of the budget, General Dawes,—a man of action, a man of brains. When he provided in the first budget that was ever presented to a Congress of the United States for the expenditure for all our rivers and harbors, how much do you think he estimated? We have been talking about one half a billion or 500,000,000 dollars as the cost of the development in the international section of the St. Lawrence. And on the 50 per cent basis, one half of that would be 250,000,000 dollars. But it is not the 50 per cent basis at all, that is proposed by the Joint Commission organized by Canada and the United States to study and report on the St. Lawrence route and what we are considering today is what the Joint Commission recommends. They have been asked to investigate and to report upon this subject and we are proposing to act on their report. They do not propose that the United States shall bear one half of the expense of this great undertaking. They say that the disproportion in wealth, in population, in commerce, between the United States and Canada shall disappear, that we shall bear—the two countries shall bear,—that expense in proportion to population, wealth and commerce, and that means, as you all know, that the United States shall bear nine-tenths of the cost. And we don't stop there. A great canal has already been dug, the Welland Canal. It is practically completed. Its expense has been borne by the Dominion of Canada and this Joint Commission proposes that the United States shall share in the same proportion the cost of that canal.

We have done the work of improving the Great Lakes. We have dug the canals, we have improved the harbors, we have done all the work that leads to their enormous commerce, the cheapest commerce in the world that floats down from Duluth all the way to Buffalo. And if we should pay nine-tenths of the cost of this canal, which Canada has already constructed, why shouldn't Canada come over and bear its proportion of the cost of this work which we have done for many, many years and which we are still doing?

When as I say, General Dawes began to consider what he would allow to the United States for all of its rivers and harbors in this great country of ours, with about five thousand miles of sea and gulf coast, with 25,000 miles of navigable rivers, with 25,000 more that can be made navigable, how much money, as against nine-tenths of somewhere from 500,000,000 to a billion and a half, which is proposed for this one route, how much do you suppose the General expected to allow us for all of this commerce within our country? Thirteen millions of dollars. And that is all he thought that the present conditions of this country could allow, with its burden of taxation, with the people paying high prices, as Mr. Cooper says, for labor and for supplies, and for materials.

The Committee on Rivers and Harbors convinced him that he was wrong, convinced General Lord, the Finance Officer of the War Department, convinced Secretary Weeks that he was wrong, and as a result they consented to 27,000,000 dollars. At that time we expected 15,000,000 dollars could be used from unexpended balances to the credit of River and Harbor projects, and it turned out that there weren't unexpended balances available. So we went on the floor of the House and we had to make a fight and a strenuous fight, and a fight for which we had to prepare for four or five weeks, in order to enable us to get an additional 15,000,000 dollars for our rivers and harbors.

What was the condition of our rivers and harbors? Why did we need this money? We needed it for two reasons. First, during the war not a dollar's worth of work was done upon any river or harbor in the United States, for the Secretary of War must have certified that it was necessary to win the war. Since it could not come within that definition the harbors were allowed to silt and fill up. And let me give you an illustration. Down in Mobile we adopted a project for deepening the harbor thirty feet, many years ago, and today the harbor in Mobile has less draft than it had when we adopted the project and what is true of Mobile is true generally of the rivers and harbors in the United States, they have been going backward instead of forward ever since the war broke out.

In addition to that this country is growing very rapidly and we need to use all of our transportation facilities, and keep furnishing and supplying new ones from time to time to meet the constantly increasing and multiplying demands of commerce. And on that

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account it is necessary that we should have our rivers and harbors used to their maximum.

One other thing. Owing to the way that the railroads were managed during Government control, owing to the fact that their operation became enormously more expensive, owing to the fact that freight rates in consequence have soared to an unheard of level, the only relief in sight was by cheap transportation by water, and how could we have it unless we improved our waterways? And then we had living examples of the fact that it was important to improve our waterways. All we had to do was to look to the south of us and we found on the Mississippi River that under Government management, which is always wasteful, always inefficient, we found that in spite of that Government boats are being operated there under Government control, and with all of the wastefulness, with all of the extravagance, with all of the inefficiency of Government operation those boats are paying, taking into account every kind of an overhead charge which it is possible to put into the account against them.

How has it come about that this traffic upon the Mississippi, for the first time in the history of the stream, is really profitable? In a very natural way. In the olden days they used to fit out a barge on the Ohio River and they would send it down the Ohio and down the Mississippi and when it reached New Orleans they would break it up and sell it for firewood. Why? Because they couldn't get a return cargo and it cost more to take it back up the river unloaded than it would cost to build a new raft up on the Ohio. And for the first time in the history of the Mississippi they have found that they can get return cargoes to the full capacity of all the boats, and that is what has made the navigation of the Mississippi profitable, in spite of the drawbacks to which I have referred.

That is only one example of the use to which we can put our waterways and of the necessity of using them. So here we are, from the Governmental standpoint in this position, of needing great sums of money to improve our own waterways in a time when we owe a huge debt and must economize, and we want to examine the whole thing carefully and fairly. We are all Americans, we all have the interests of the whole country at heart. If it is the best thing to build this waterway we want to build it, but we don't want to decide it as a matter of sentiment, we don't care to decide it as a matter of feeling, we want to examine it soberly as we would examine any other business question in the light of the facts, and see whether it will bear such an examination.

We find that it is well nigh impossible to get what our own waterways need as a sheer and dire necessity, we find as we look back over the history of the past twenty years that we have only had about 30,000,000 dollars a year for all our waterways. We find that last year we spent 40,000,000 dollars. We find that it is going to be necessary to spend 100,000,000 of dollars a year on the waterways in the United States to develop and maintain them. And yet as I say, those in charge start off by offering us 13,000,000 dollars to meet a necessity that requires 100,000,000 dollars.

In the face of facts like these, should we not examine a proposal to spend hundreds of millions of dollars on one waterway traversing a foreign country? Isn't that fair, that we should examine it closely, that we should scan it, that we should be entirely satisfied before we reach a conclusion?

Let us take the report of the Joint Engineers, first of all, and see, because that is what we have before us, what they propose. They say that we are to have a channel of 25 feet through the St. Lawrence, and then say we are to be satisfied with the channels in the Great Lakes, except that in the pivotal harbors and through some of the channels we may get an increased depth from 20 to 21, 22 or 25 feet, which are the controlling depths today. What is the situation as to that depth? Is that depth sufficient for the purpose for which it is intended? Is it going to enable ocean going vessels to traverse the St. Lawrence route,—ocean going vessels of a size that can compete with the lake freighters that now carry the traffic of the lakes? We have on the Great Lakes today freighters carrying 14,000 tons, and everyone knows that is the cheapest transportaion anywhere in the world. These great freighters are practically square boxes which require scarcely any space for coal, they are loaded and unloaded in an incredibly short space of time and owing to the fact that they don't need the reserve space, that loading and unloading is so very cheap, that the cost of construction is very low, transportation on the Lakes is, for its cheapness the marvel of the world.

I don't know myself the comparative average costs of transportation on the Great Lakes and of that on the ocean. I recently had the pleasure of having a joint debate with Senator Ransdell of Louisiana, an ardent advocate of the St. Lawrence route, at Boston, when Mr. Harriman, who is to follow me, was present and in that debate Senator Ransdell made the statement that the average cost of transportation per ton per mile on the ocean was three mills, and that the average cost on the Great Lakes was one mill. Now I know nothing about the accuracy of his figures, but I am reliably advised that the cost of transportation on the ocean is much greater than the cost on the Great Lakes. So starting with that as a basis, I ask how you can, for the purpose of economy, substitute ocean navigation, which is far more expensive than navigation on the Great Lakes, for shipment by lake freighters and yet cheapen the cost of transportation to the wheat grower of the northwest? You start with that as your primary proposition and then you come to examine the details, and see whether it is simply the average cost of transportation on the Great Lakes and of transportation on the ocean, that you have to meet, or whether there are other factors that enter into the problem and make it

more clear still that you cannot compete by an ocean going boat with the cost of transportation which is established today by the lake freighter. What kind of ocean going boats, what capacity of ocean going boats will be able to traverse the Great Lakes? That is your first problem. Here you have a depth, a controlling depth of 20 to 22 feet, because your boat must be able to traverse the very shallowest section. The steamship companies say that the largest sized boat, that could traverse the Great Lakes and its channels and harbors, would be one of 4000 tons capacity, and they would have to compete on the Great Lakes with these freighters carrying 14,000 tons. What would the result be? You wouldn't have the ordinary competition between the cost on the ocean and the cost on the Lakes, but you would have in addition to that, not a competition between two boats, one an ocean boat carrying 14,000 tons and another a lake freighter of the same carrying capacity, but you would have this small, insignificant ocean boat, which isn't large enough to be economical on the ocean competing with a 14,000 ton lake freighter, 4000 tons is all that could be carried in an ocean ship upon the St. Lawrence route. Can there be any doubt that the 14,000 ton Lake freighter would carry freight very much more cheaply than the 4000 ton ocean ship?

Before I leave that question of depth, let us go to another demonstration of the fact that the proposed depth would be insufficient. The Joint Commission in its report says that the controlling depth from Montreal to the sea, a distance of a thousand miles, is 30 feet, but they say that that is being improved to 35 feet. What does that mean? It means that Canada and Great Britain have used that channel for ocean going vessels for a very long time and as the result of all of that experience they have found that 30 feet even isn't a sufficient depth, and that to navigate the channel economically, to get the best results, the lowest freight rates, and to make it profitable to use the channel, you must have a depth of 35 feet.

So here is the channel from Montreal to the sea, one thousand miles long and it is proposed to supplement that by a channel, from Montreal west, of twenty to twenty-two feet, and join together that mismatched, dissimilar pair and call it a joint and complete route. Of course it is utterly impossible.

What next do you find? That there isn't simply the disproportion of costs between the lake freighters and the ordinary ocean going boat, but that there is a great difference because they are built on an entirely different principle. The one is built much higher than the other, the ocean vessel having to be built for the buffetings of that enormous expanse of water. But you don't have to build simply the ordinary ocean going boat for the St. Lawrence route. The Encyclopedia Brittanica in its latest edition says that for the navigation of the St. Lawrence route you must have an especially strongly constructed vessel because of the fact that icebergs are present in that channel at all times of the year.

That adds to the overhead, and to the cost of construction; the interest charges, as Mr. Cooper pointed out, go on, and as a result, the cost of carrying the wheat, if you are going to carry it in that ocean-going vessel, is increased by the interest on that added cost of construction.

Then the Joint Commission says that it is not simply a question of fogs, tides, nor icebergs, but the combination of all of these difficulties and dangers of that route, there resulted in 1909 the adoption of what was known as the British North American Clause of Marine insurance requiring a very high marine risk rate all through the St. Lawrence. The Joint Commission in this report recommending this route says that that is a handicap to the usefulness of the route.

Those are a few of the objections to this route. Mr. Redfield, Secretary of Commerce, investigated this matter in 1918 and made a report in which he said that there never would come a time when ocean-going vessels would carry freight in the restricted channels of a canal or a river or upon the Lakes, that the over-head makes it absolutely impossible, the cost of construction, the cost of maintenance, the cost of operation was so very much greater for all boats of that description.

A report was made by the Army Engineers at about the same time, and they reached the same conclusion. I don't understand that any Board of Army Engineers has united in this report of the Joint Commission. My understanding is that a single Colonel from the United States Army was designated on our part, and an Engineer on the British side was designated, and those two engineers joined in the making of this report.

Let us take this St. Lawrence route and examine it regarding waterpower. It runs along the American border for a very short distance. In that distance there occurs one of the opportunities to create water power. Every one in the United States is in favor of the development of the water power on the St. Lawrence, on the Niagara, at every point in the United States where it can be developed. It is the one thing since I have been in Congress that has been my especial care, for which I have fought incessantly, day in and day out, ever since I have been a member of that body, because in the district, which I have the honor to represent, there is located the greatest water power in the world, the power of Niagara. We have developed a small part only of the great power there and I have seen a little village of 3000 people grow to a city of 60,000 people, (with $200,000,000 of assessed valuation), which is the greatest electrochemical center in the world, I saw there the development of more of the things that went to the successful prosecution of the war than were made at any other point in this great and rich nation of ours, with all of its broad territory. So, of course, I believe in the development of power, everywhere throughout our country. But the develop-

ment of power anywhere, if the power is worth developing, doesn't have to be done at Government expense. Go down and examine the applications for the development of water power in the Federal Power Commission at Washington. Talk with the Secretary, Mr. Merril, find if there is any water power that is worth having for which there isn't an application pending. Find if there aren't competitors in each case where the power is worth anything. Find if men aren't eager, not ready, but eager and ready to advance the money at a moment's notice, the instant they can get the license. That is the situation as to the development of power.

Then if anyone says to you, "Why, you can do better by Government development than you can by private development," say to him, that he can look back to the period when the Government controlled the railroads and it had them for only 26 months under operation and say to him that during that period the Government lost the stupendous sum of one billion dollars, one twenty-sixth of its total national debt today incurred by reason of the war. And say to him that you had the poorest service during Government operation you ever had in the history of your country and if he wants a practical illustration, tell him that you couldn't trace a freight car from the time it left a yard until it reached its destination, if it ever reached it. And then tell him, if he wants a particular instance of how bad it was, to go down into New England and find their roads practically ruined and if he will examine the records he will find that during the first 18 months of Government control they earned only 15 per cent of the standard return,—of the average of their earnings for the three years preceding Government control,—and, then if he says to you, "Why, railroads are not water power, and we are talking about water power," tell him to go down to Niagara and visit both sides of the river there and then go on to Quebec and tell him he will find that on the Niagara, on the American side we furnish power 40 per cent cheaper to the consumer than they do over on the Canadian side where it is government controlled, and then tell him to step down to Quebec where it is developed by private enterprise and he will find that it is produced there 32 per cent cheaper under private enterprise than it is by the Government.

So far as the Government part of this is concerned the Government doesn't need to, and shouldn't, take any hand in the development of the power, and there isn't a man in the United States who recognizes more fully than I do, the importance of power development or who is more earnestly, in season and out of season, every day of the year, for water power development.

Let me say one word more about this question of water power. Many people say to you that water power will pay the entire cost of the improvement of the St. Lawrence. Well I say to you that as a matter of law, it can't do that and as a matter of justice and fairness it shouldn't do that. This water power will be developed under the General Water Power Bill and I had the honor personally to make the fight which kept boundary streams in the General Water Power Bill. You have the legislation ready and all you have tc do is to give private capital the opportunity to develop the power.

The General Water Power Bill provides this,—and it is not going to be changed because it is a just and fair bill,—it provides that when the state where the water power is developed has a Public Service Commission, that that Public Service Commission shall regulate the charges. On what principles are they regulated? They regulate them on this basis,—they allow the companies to prove what it costs per horse power to develop the power which they are selling. They allow them a reasonable sum for depreciation and amortization and then they allow them a reasonable profit. Now how are they going to allow for something that hasn't anything to do with water power? Because navigation has no connection with water power, navigation is an entirely separate and distinct thing. How can they allow those who develop the water power to charge the consumers of the power for the development of navigation in the St. Lawrence? It can't and shouldn't be done and we shouldn't, for one moment, delude ourselves with any dream that we are going to pay the entire cost of improvement of navigation out of the development of the water power. Why, this country needs the improvement of its transportation facilities. All along the Atlantic Coast, starting in from Boston and Portland, including every southern port, Baltimore, Savannah, Charlestown, Mobile, Galveston, New Orleans, every port is growing from day to day and year to year in its commerce, and most of these ports are growing rapidly in the export of wheat.

Do you realize,—and it seems impossible for those who haven't examined it to realize it,—do you realize that on the Houston Ship Canal they are carrying 10,000,000 tons of freight a year? Of what kind? They are carrying that material which is just as useful as water power,—oil. And it is increasing in quantity from month to month and they have found down there that it is not economical to have a 25 foot water-way, on that little stream leading up from the ocean, only about 50 or 60 miles long. They have found that 20 to 22 ft. depth wouldn't do. They have 25 feet and they are before Congress at this session to get it increased to 30 feet and the Committee, of which I have the honor to be Chairman, has reported a bill to give them their 30 feet depth. There isn't anything any more important to the development and the progress of this nation than the use of oil and its various products. There isn't anything that is multiplying in its use from day to day, with anything like the rapidity of oil, and there is no place where it is being shipped as it is down in those gulf ports. And there is one of the things that you have to do. We haven't any money in this Bill for deepening these harbors. We are simply going to

adopt the project and then trust to Providence that we can persuade Congress that it is necessary to let this oil come to us just as cheaply as it can, let the cost of gasoline go down five cents, if it is possible to do so take it out of the transportation costs. Isn't that a real problem to be weighed against the St. Lawrence route? Isn't it as important to us as developing a waterway in the foreign country? And that is only one of our pressing needs. Here is the Ohio River. Congress over 26 years ago adopted the project of improving the Ohio River by locks and dams. In 1910, after seven of the 54 locks and dams were completed, we provided that we should complete that improvement within 12 years. Twenty-six years have passed. We have improved 500 miles of it, about half, and the rest remains to be done.

The Ohio runs between coal mines and forests, rich fields waving with grain and all the products of the soil and, in its upper portion, through a beehive of manufacturing plants which have caused that section to be called "The Workshop of the World;" and cheap transportation can be had to carry all these products from Pittsburg, Cincinnati, St. Paul, St. Louis, New Orleans and intermediate points; and all of those great American cities which we love just as much as we do Montreal and Toronto, which are just as near our hearts; yet how are we going to get the money to complete this great transportation project if we spend hundreds of millions of dollars upon one foreign waterway, when it is hard to wring thirty millions of dollars out of an unwilling Congress for all the waterways of this great country of ours.

And then the Mississippi flows down dividing our whole empire of states, with great grain fields on both sides of it, furnishing to the vast territory tributary to it a far shorter route to the sea than the St. Lawrence route, and the southwest pass needs to be improved, and it will take millions to complete the work. Where are we to find the money if we spend all our income on the St. Lawrence? We never have provided that the nation should deepen the harbors on the Mississippi and they are all filled and silted and haven't the requisite depth. Don't we need the money to do that? Shouldn't we provide it? Don't we love all those cities down there just as much as we do Canada? And isn't it just as important to the life and the prosperity of this nation as a whole, that that great river be improved?

And so you could go over the various waterways of the United States, taking them one by one, pointing to their use in the national system of transportation. Why, as I think of this St. Lawrence route, I think of something that is in the mind of this nation because the President has recently brought it to the attention of Congress. I think of the fact that during the war, at an enormous expense, at the expense of billions we built up a great Merchant Marine only to find that the effort to operate it lost us a million dollars a day for the 365 days of the year. And finally we threw up our hands in despair and said that we couldn't stand the losses and that we had demonstrated that the Government couldn't operate ships, and the President came to Congress and said that we must sell these merchantships, these hundreds of thousands of tons that we had built at this enormous expense, let them pass into private hands, but under the American flag. But he said it was demonstrated with equal clearness that owing to our high cost of labor it was impossible for private parties even with efficiency, with energy, with capacity, with all that goes to make business successful, it would be impossible for them to operate those ships successfully in competition with the cheaper paid labor of Europe and with the experienced seamanship of those countries, and so he proposed that we should subsidize the American Merchant Marine, pay them 30 to 50 millions of dollars a year in order to enable them to operate upon the ocean, as Congress is going to do it, in my judgment.

If it is impossible for an American Merchant Marine to operate upon the free ocean, the Atlantic and the Pacific, with all the advantages they offer, how I ask you, when you can only bring up the St. Lawrence a boat with 4000 tons capacity, which is uneconomical even on the ocean itself where they require at least 7500 to 10,000 tons to be economical, how are you going to induce private enterprise to enter upon any such business venture as navigating ocean ships of that capacity on the St. Lawrence route? Deepen and widen the St. Lawrence, spend your hundreds of millions of dollars, starve your own waterways in the United States, do this for a third of the life of one generation, ten years, and when you have the waterway there ready, to the depth and of the draft that the Joint Commission recommends, what are you going to do with it when you can't operate ships upon the ocean of proper tonnage to be economical, when you can't operate them without a subsidy, how are you going to get any one to operate them upon the St. Lawrence route?

And are you going to come then and ask for a subsidy for this route for a thousand miles up to Montreal from the ocean and then on to Duluth? And do you think that the nation is in condition to grant the subsidy or that they will believe in the enterprise when they have examined it sufficiently to subsidize the boats that would navigate the channel? I am thoroughly convinced that this is a vision, and let me, in closing say, that I have had a vision of a different kind for this country. I have had a vision looking out across the sea and down there to the country to the south of us, South America, Mexico, and Cuba, of vast lands, with wonderfully natural resources, all undeveloped, all waiting simply the touch of enterprising Anglo-Saxon man to turn them into gold as fast as they are touched.

And I have thought of these three millions of boys who went abroad to save the country in its hour of danger, and I have coupled them with this great

Merchant Marine, and I have seen them manning that Merchant Marine and taking it down to that southland and developing that great country, with its vast natural resources, and not only making the fortunes of these boys and of the shipping enterprise, but increasing and adding to and multiplying the riches of this country.

Why, I believe that those boys had natural capacity, and I believe that it has been enormously developed in the war, and I will tell you a little story to illustrate that, and then I will close.

When the war was entering on its final year, Marshall Haig and Marshall Foch met and had a conference and they said "It takes to make a good soldier, nine months of training behind the lines and then six months in the lines." They said, "America has had the time behind the lines, but she hasn't had any of the time in the lines, and she can't come in this year, 1918, and help fight this war."

When the American boys reached Europe in the year 1918, without having been in the lines, they were put in the front lines and soon they were given a sector in proportion to the number of men they had. It was their prowess, and their ability, and their valor, that soon stopped the advance of the Germans and turned what had been a retreat into an advance and there never was anything except an advance from that day until Armistice Day. And I believe that these boys manning this Merchant Marine, (instead of going into another country), improving and utilizing the rivers and the harbors of this great country of ours, can go down and conquer that South and Central American, Mexican, and Cuban trade and bring as great a commercial victory, as they brought martial victory in the war, to the glory and the prosperity of this country, and of all of us.

A Million Volt Testing Set--II

BY A. B. HENDRICKS, JR.

Associate, A. I. E. E.

Transformers Engineering Dept., General Electric Co., Pittsfield, Mass.

(Concluded from page 805)

The design and construction of the three 500-kw., 578,000-volt transformers and of the 500-kw. insulating transformer were given in Part I of this paper[1], which included also illustrations of single-phase arcs between sharp points, spaced 9, 11 and 14 ft. apart and corresponding to the crest voltages of sine potential waves having effective values of approximately 1,000,000, 1,200,000 and 1,500,000 volts.

Three Phase Arcs. Photographs of arcs taken with the three main units connected delta-Y with grounded neutral are reproduced in Figs. 25 to 31 inclusive, the general arrangement being shown in Fig. 25.

The spark gap consisted of sharp pointed brass rods arranged with the points at the corners of a horizontal equilateral triangle, measuring nine feet between points on each side. In these tests there was no neutral arcing point, but the arcs seemed to form indifferently in either delta or Y. Doubtless the Y formation is always preceded by a single-phase arc, but as the arcing voltage between points is closely proportional to distance, at least for high voltages, there is always a strong tendency to form the Y and to the eye it appears instantaneously. Actually there is a million-volt electric field revolving at 3600 revolutions per minute.

The left hand point in Fig. 25 was connected to the unit placed in the large tank and excited through the insulating transformer as it was inconvenient to change the connections. This inserts additional capacitance and reactance in this leg of the high voltage Y, thus raising the voltage so that there is a slightly greater tendency to arc from this point to either of the others than for an arc to form between the other two points.

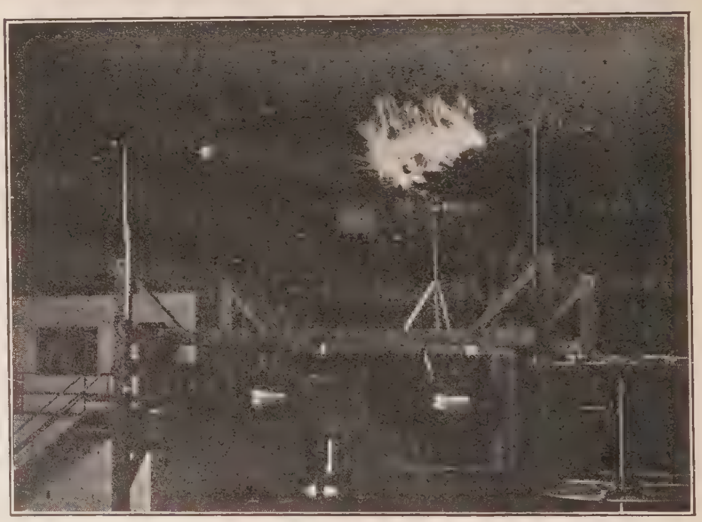

Fig. 25—1,000,000-Volt, 9 ft., Three-Phase Spark Gap With Single-Phase Arc (One Phase Reversed)

In the first test there was no means of determining the polarity of this leg except by trial, and as shown by the illustration, it turned out to be reversed, so that only a single-phase arc was formed between the other two legs.

1. A. I. E. E. Journal, October, 1922.

Reversal of the connections produced the three-phase Y-delta arc shown in Figs. 26 and 27. This is somewhat distorted by being seen nearly edge on from a position below the plane of the spark gap. This was really an open delta-Y arc as there appears to be no direct arc between the two right hand points.

Since the arcs form almost indifferently in any combination, single-phase, open delta, delta or Y, and follow each other in rapid succession, the arrangement shown in the illustration is a matter of chance.

In making the three-phase tests there was no resistance in the high-tension circuit other than the high resistances paralleled by the choke coils.

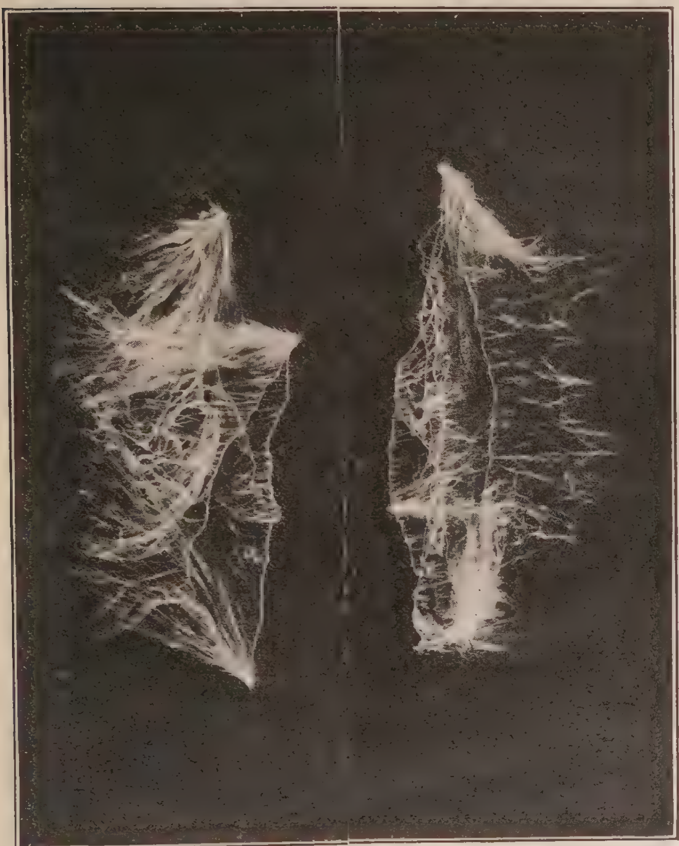

Fig. 26—1,000,000-Volt, 9 ft., Three-Phase Arc Showing Both Y and Delta Arcs

Fig. 27—1,000,000-Volt, 9 ft., Three-Phase Arc Showing Y and Delta Arcs

In Figs. 28 to 31 inclusive the camera was placed on the floor of the supporting structure shown in Fig. 25 pointing directly upward to the neutral point of the arcs, thus showing them in their natural position and about 10 ft. above the camera.

All the arrangements in taking these last photographs were identical with those of the previous three-phase photographs, but the low-tension voltage was about 10 per cent less, presumably because of different atmospheric conditions. The spacing of the gaps was nine feet as before.

Although less than one million volts were required to start the arc, the generator excitation was greatly increased by means of the field rheostat at the instant of the first discharge so that the actual arcs were formed at an unknown voltage, but approximating one million.

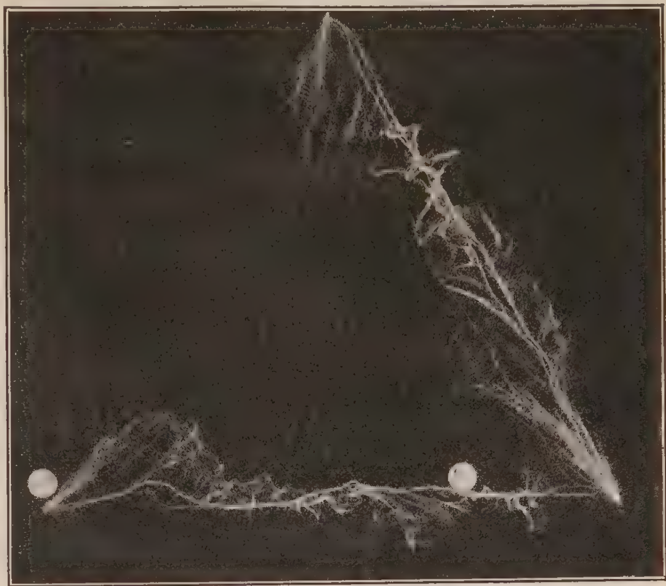

Fig. 28—1,000,000-Volt, 9 ft., Three-Phase Arc Forming in Open Delta

Unless otherwise indicated, all voltages given in this paper are effective values of a sine wave having the same crest value as that actually observed. The generator potential wave form was always close to a true sine wave.

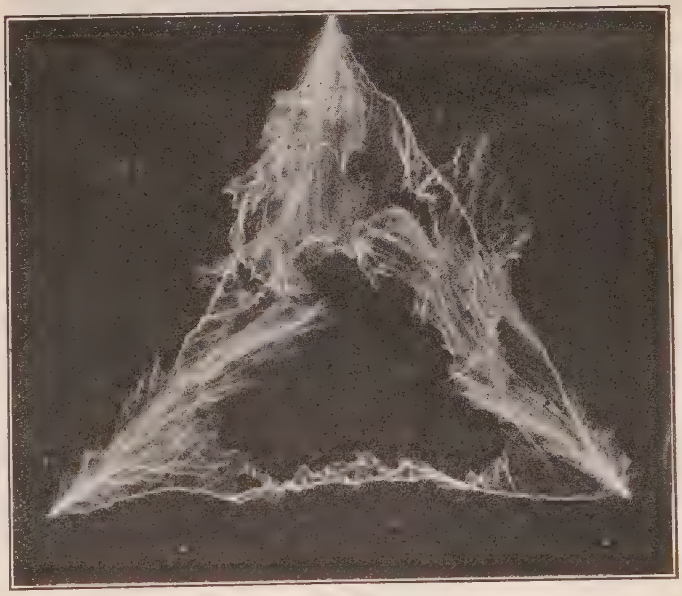

Fig. 29—1,000,000-Volt, 9 ft., Three-Phase Arc in Delta Formation

With two units connected in series for one million volts to ground, the high capacitance gives an initial

discharge resembling a direct lightning stroke which tends to destroy any object under test such as a string of line insulators. This discharge seems to be a rapidly

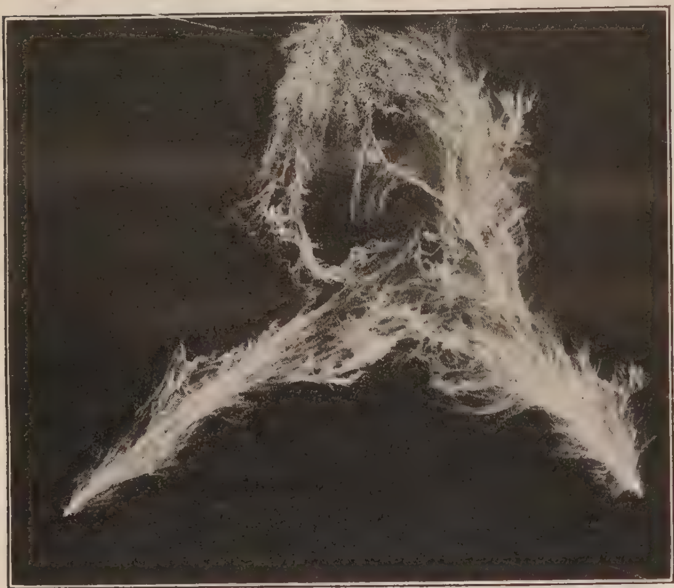

FIG. 30—1,000,000-VOLT, 9 FT., THREE-PHASE ARC SHOWING Y FORMATION AND ALSO SINGLE-PHASE

damped oscillation and is usually followed by a 60-cycle arc.

With one or more units in normal connection—that is with one terminal of the high-tension winding dead

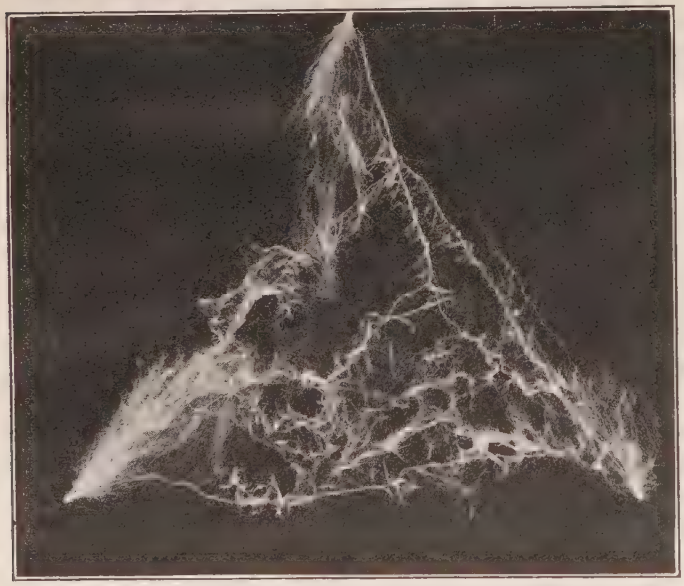

FIG. 31—1,000,000-VOLT, 9 FT., THREE-PHASE ARC SHOWING Y-DELTA FORMATION

grounded, the capacitance effects are less marked but still more severe than with testing transformers of smaller size and less inherent capacitance, and the initial discharge is practically always followed by the 60-cycle arc.

Fig. 28 shows two 9-ft. arcs in open delta, the arc failing to form on the third side. The two bright spots are incandescent lamps on the ceiling which were

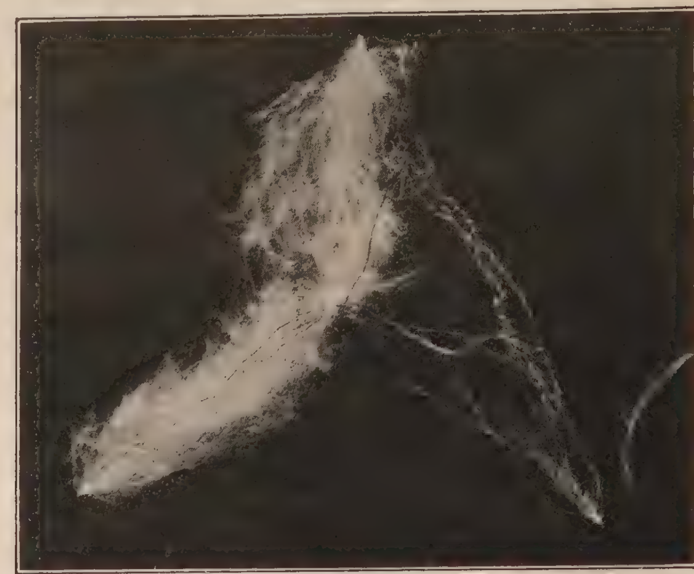

FIG. 32

inadvertently turned on before the lense was capped. Fig. 29 shows a 9-ft. delta arc, Fig. 30 shows a *Y* formation and also one single-phase arc, and Fig. 31 shows a series of 9-ft. arcs in both *Y* and delta.

Three-Phase Arcs with Grounded Neutral Sparking Point. Further tests were made with a fourth sharp

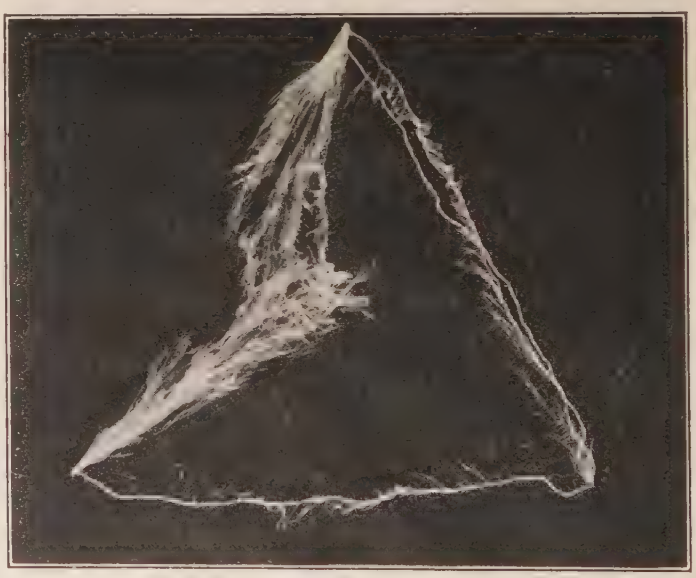

FIG. 33

point placed at the geometric center of the delta and grounded, being supported from above.

This caused the *Y* arcs to predominate, and to restore equilibrium the neutral sparking point was raised about one foot above the plane of the delta. The potential of one point being somewhat higher than that

of the others, as already explained, it was moved out about six inches in some of the tests. This is the upper left hand point in the illustration. The curved streak near it is a reflection of one of the balls of the 75-cm. ball gap, which was near the camera as shown in Fig. 25, but not connected to the circuit. No series resistance was used in these tests.

Fig. 32 shows single-phase and *Y* arcs, two legs of the *Y* tending to predominate. This was an exhibition arc repeated many times, the arcs holding until they had run up the neutral conductor about 6 ft.

Fig. 33 shows two legs of the delta and two of the *Y*. The initial discharge of the capacitance (pilot spark) resembles a cotton rope partly untwisted and shows about three oscillations. This effect appears on many of the photographs and justifies the statement that the first discharge is usually oscillatory and rapidly damped. Theory indicates the same thing.

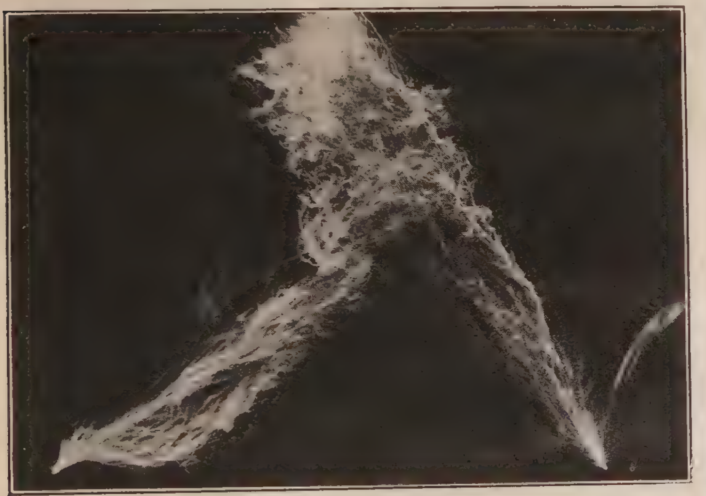

Fig. 34

Fig. 34 shows both single-phase and *Y* arcs and Fig. 35 is a good imitation of the Scott connection.

In Fig. 36 one transformer failed to arc, but a discharge occurred from the neutral to the middle of one side of the delta. The oscillatory character of the initial discharge is clearly shown.

Fig. 37 shows arcs from neutral to two corners only. The grounded neutral sparking point was removed for the next two illustrations.

Fig. 38 gives three single-phase arcs and a Scott connection. Compare with Fig. 35.

Fig. 39 shows a peculiar formation of great beauty. The arcs are doubtless extremely sensitive to atmospheric conditions, the path of the circuits and the proximity of conductors, especially if grounded, and naturally show infinite variety of form.

Tests on Line Insulators. In these tests two transformers were connected in series for 1,000,000 volts to ground. No series resistance was used.

Fig. 40 shows a 60-cycle arcover to ground on a string of 20 Hewlett insulators, a distance of about 10 ft. at about 950,000 volts. The arc went wide of the insulators, even farther than appears from the illustration.

Twelve units from the same string were then arced over several times, the last series at 608,000 volts being shown in Fig. 41, but the 60-cycle current failed to

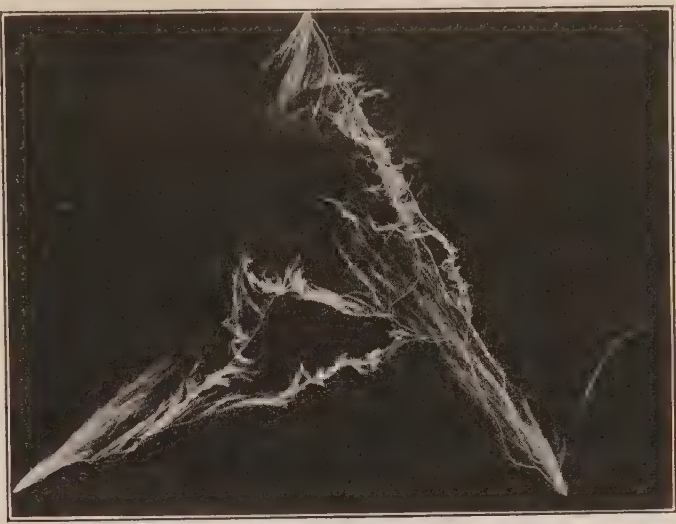

Fig. 35

follow. After this test, six of the units were found punctured, pieces of the porcelain being shot off bodily in some instances, although these same units had been repeatedly arced over without damage in previous ungrounded tests on an older transformer. Evidently the different characteristics of the transformer combined

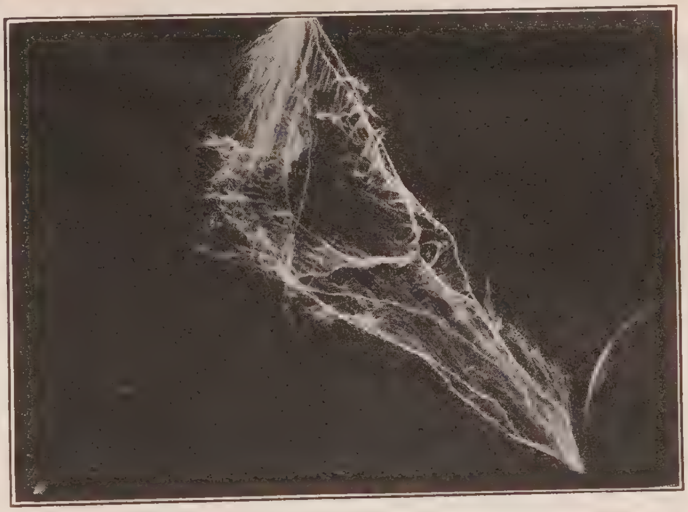

Fig. 36

with grounding of the insulator string led to a great difference in the results.

The new transformer is of greater power and capacitance and lower reactance than the old, the generator and method of test were the same. A later test on perfect insulators gave the same results, the arc would not hold and several units were punctured.

Effect of Parallel Reactance in Low Voltage and Series Resistance in High-Voltage Circuit. It has been shown that these transformers take a leading exciting current at a power factor of about 27 per cent which remains nearly constant through the whole range of voltage.

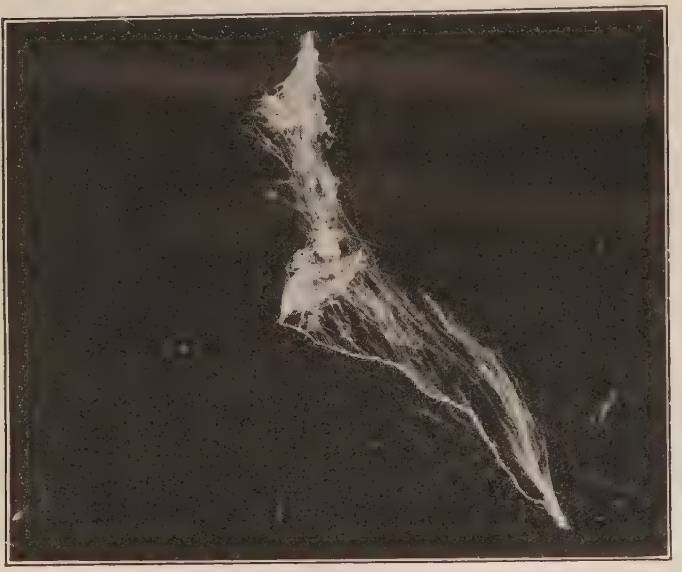

FIG. 37

In the last test the generator current was 97.5 amperes and field current 16 amperes. This is an abnormally low field current, the excitation being produced largely by armature reaction of the leading current. The voltage is therefore unstable and at the instant of arc-over when the load changes suddenly from

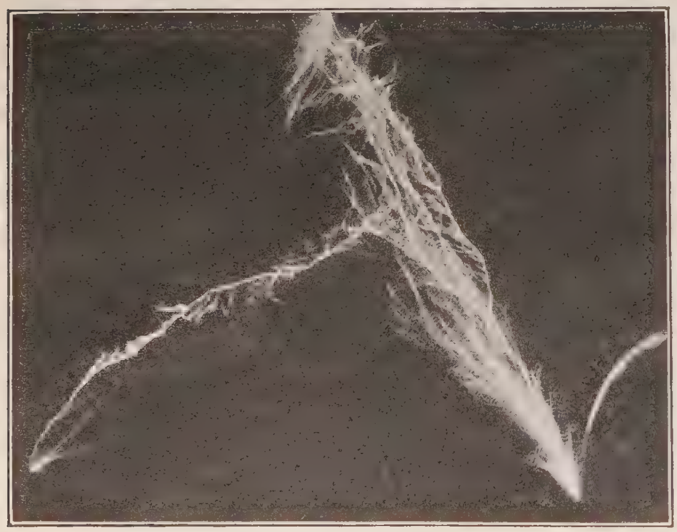

FIG. 38

leading to a short-circuit lagging current, the generator voltage suffers a large drop. It was thought that the addition of a constant large lagging load in parallel on the low-voltage side, would stabilize the voltage since a much higher field excitation would then be required for the same generator voltage.

Accordingly a power limiting reactance (without iron) of 11.5 ohms was connected across the loaded phase and the test repeated. This reduced the generator current from 97.5 to 34.5 amperes and increased the exciting current from 16 to 35 amperes. The arc then held somewhat better but the insulators punctured as before. The reactive load stabilizes the generator voltage but does not decrease the destructive effect of the first discharge.

Fig. 42 shows the arc without reactance, several of the units being punctured at about 655,000 volts. Fig. 43 shows a 60-cycle arc on 12 perfect insulators at about 665,000 volts with the reactance in parallel with the generator. Several units appear to be punctured. After two more discharges three units were found punctured and were replaced with perfect ones.

A resistance of 120,000 ohms, consisting of 28 carborundum rods was then hung from the insulator

FIG. 39

string and connected in series with it, the reactance being disconnected.

The resistances arced over, as well as the insulators, but the arc failed to hold.

Finally, the reactance and resistance were tried together, the reactance in parallel with the low side, the resistance in series with the high side. The initial discharge, while arcing over the resistances as before, as well as the insulators, was followed by a heavy 60-cycle arc around the insulators, the 60-cycle current also passing through the resistance after the first impulse. No photographs were taken of these last two tests.

In all of these last tests there was little variation in arcing voltage, though there was a number of punctured units in the string in some instances. Apparently the action may be made anything desired by variations in circuit constants and it is a question which condition is most suitable for a given test.

The same transformers will give an impulse test, a

60-cycle arc-over, or a combination of both, but the last is much more severe than the usual tests of past experience.

It should be remembered that the actual voltages are not only greater, but also higher to ground and therefore approach more nearly to abnormal service conditions.

The two transformer units have a combined capacity of 1000 kw. at 6 per cent reactance (plus the insulating transformer) and very high internal capacitance, so that extraordinary effects are just what should be expected.

The three-phase nine-foot point spark gap test was repeated with 23 ohms reactance across each low-voltage winding and it was found that the 60-cycle arcs held

Fig. 40—Arcover of 20 Hewlett Insulators (About 10 ft.) at 930,000 Volts to Ground

better than without reactance, which confirms the single-phase results.

Perhaps the effect of capacitance could be modified and controlled by the use of a water jet or other suitable resistance between line and ground.

Wave Forms. The two generators are on the same shaft and while each is rated 500 kw. single-phase, it is wound three-phase *Y*-connected and is good for 750 kw. three-phase.

With the two generators in parallel the normal capacity is thus 1500 kw. or the same as for the three main transformers connected three-phase. These generators were especially designed for a sine voltage wave, and the variations therefrom are small over a wide range of conditions.

It is often stated as a general rule that a leading current distorts the wave form more than in-phase or lagging currents. This may often be true but as a general statement does not hold, it depends on the design of the generator.

In the test on 12 Hewlett insulators at about 650,000 volts, the wave form was as good with high leading current as with low lagging current.

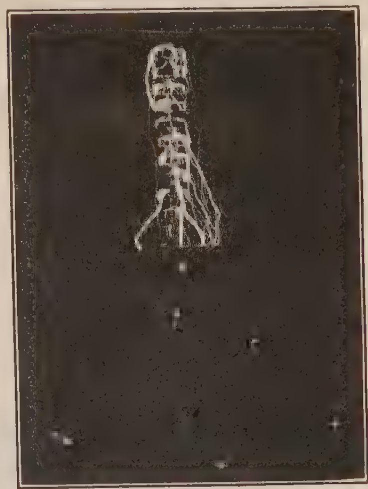

Fig. 41

With the reactance in parallel and 34.5 amperes lagging armature current, the amplitude factor (ratio of crest to effective value) of the voltage wave was 1.399.

Without the reactance and with 97.5 amperes leading armature current, this factor was 1.395. In both cases

Fig. 42

the variation from sine shape was thus about 1 per cent. The wave form was nearly perfect with no appreciable ripples, but more symmetrical with leading current.

The reactance of the main transformer is 6 per cent, the errors of the voltmeter coils at full load, zero power factor leading, is under ½ of 1 per cent and of the order of 1/10 of 1 per cent under the conditions of the tests

described, while for a single transformer at least, there is a difference of only about 1 per cent between voltages determined by the conversion ratio and the voltmeter coil. The values of high voltages given herein are as referred to a ball spark gap which responds to transients of extremely short duration, and the difference between the conversion ratio and gap voltages is as follows, in round numbers at full voltage:

7 ½ per cent for one transformer.
17 ½ per cent for two transformers neutral grounded.
22 ½ per cent for two transformers one end grounded.

In all cases the ball gap indicates a higher voltage than the conversion ratio or voltmeter coil.

The differences cannot be accounted for by variation of generator wave form (1 per cent) by errors of conversion (1 per cent), or voltmeter coil (1/10 of 1 per cent), nor by errors of instruments or observation. The cause must be transient voltages which are always

Fig. 43

present and whose effect seems to increase faster than the voltage and thus reaches a high value with the extreme potentials under consideration, or resonant conditions in some part of the circuit.

In referring to test voltages it is therefore pertinent to ask, what voltage? as it may be the average, effective, crest or transient value that is meant.

There is also a difference in transients. The point gap does not respond as quickly as the ball gap and may indicate less than the maximum instantaneous voltage. In the present series of tests with point gaps the voltage was checked by a 75-cm. ball gap up to 650,000 volts to ground and 950,000 volts with neutral grounded which was as high a voltage as the old spark gap would stand, the new 100-cm. gap being unfinished.

The point gap, distance-voltage curve has been determined with some accuracy up to 1,000,000 volts (106 inches) and being close to a straight line through the origin of coordinates could be produced to 1,500,000 as a first approximation at least. This also could be checked by the ratio of ball gap to the conversion voltages of a single unit.

Fig. 44 represents a tentative calibration, a straight line from the origin through 106 inches at 1,000,000 volts as previously determined by F. W. Peek, Jr. The three plotted points correspond to those of this paper at 108, 132 and 168 inches (9-11 and 14 ft.) for 1,000,000, 1,200,000 and 1,500,000 volts respectively and are given simply to show that the stated voltages were actually reached and probably exceeded.

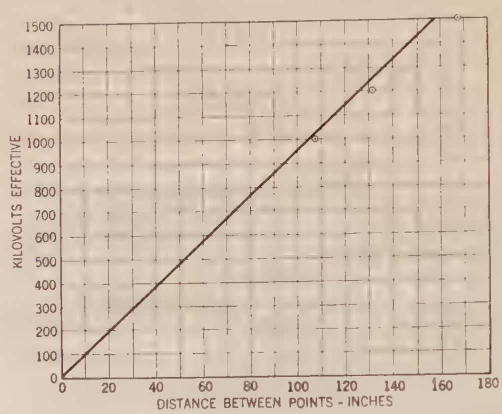

Fig. 44

The point gap is variable in behavior the results depending largely on atmospheric conditions, but the curve given is probably correct within 5 per cent. It does not hold for small spacings below 100,000 volts.

The transformer terminals act like ball gaps in not showing corona and in response to transients so that the latter set a limit to the voltage that may be obtained. As far as the transformer proper is concerned

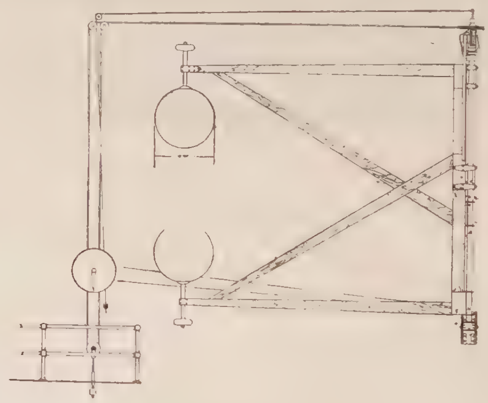

Fig. 45

it could evidently be operated at still higher 60-cycle voltages if the transients could be suppressed.

In one instance, already referred to, a discharge occurred from the choke coil on the million-volt terminal about 18 ft. due west to an iron pipe on the wall of the building, although a sparking point was mounted on the same choke coil nine feet from a grounded point due east. The west gap resembled a point and plane, the east gap was composed of two points, which may explain the tendency to arc to the west.

In one of the three-phase tests with the three units connected in Y with grounded neutral, one of the terminals arced over from cap to sleeve after a vicious series of 9 ft. arcs across the three-phase point gap at about 1,000,000 volts. Two of the terminals measure 65 in. from cap to sleeve, the third or million volt terminal mounted in the large open tank measures 125 5/8 in. This unit was also grounded, but excited through the insulating transformer, the additional reactance and capacitance raising the voltage, though but slightly. However, this terminal arced over, the two shorter ones of about half the length did not!

This is a record of some of the first results obtained with the new testing set representing the first trials which were in the nature of routine acceptance tests.

The principal constants and the characteristic curves were measured with care, but no attempt was made to obtain great accuracy in the arcing tests. When the 100-cm. ball spark gap is put into service it will be possible to extend the spark gap curves with precision to the limit of the apparatus. This is shown in Fig. 45 as it will appear when swung flat against the wall for cleaning and zero adjustment.

It will now be feasible to carry out an unlimited series of tests and researches in a region of high potential yet unexplored, but this must be left for the future to record.

The efforts of many individuals were combined in the design and construction of this apparatus. It is a pleasure to acknowledge particularly the assistance of F. B. Cahall who made the calculations, D. C. Burton who supervised construction, R. J. Woolrich chief draftsman and Royal Meeker who made all the tests.

Discussion at Annual Convention

THREE THOUSAND TESTS ON THE DIELECTRIC STRENGTH OF LIQUID INSULATION*

(Hayden and Eddy), Niagara Falls, Ontario, June 27, 1922

W. A. Del Mar: I would like to ask the author why the successive tests were made on the same sample of oil. We have done a good deal of oil testing, and have always taken the precaution to pick out fresh clear samples for the tests. I am wondering whether more uniform results would be obtained if a fresh sample of oil were used for each test, than if you used the same sample five hundred times? It would seem that the matter of the chemical decomposition of the oil would enter into the problem, and that has not been mentioned in the paper.

E. D. Clarke: We have gone into the program of the testing of the variation and the breakdown of samples of oil, which seemed to be good oil. Quite an extensive investigation of the subject, which began some time ago and I would like to know how to eliminate some of the variation.

In this process we have raised the temperature of the quantity of oil to about 150 deg. fahr. gradually, and we have found that the oil then behaves quite uniformly.

Another thing is if the sample of oil be turned other side up, a few times, the values come out closely.

As to the point Mr. Del Mar brought up in this discussion, we have made a test with different samples from the same cup, and there was a very considerable variation.

John B. Whitehead: I think that these curves show a very encouraging uniformity, notwithstanding the large value that may be given to the extremes of variation; the authors have rendered a very material service in taking this large number of observations. It brings us to a point where it is possible, to specify the properties of oil in terms of a definite figure, and a maximum permissible deviation.

I think there will be little dissent from the conclusions of the authors that the irregularities are inherent in the structure of the material itself. When Mr. Hayden presented his last paper on the breakdown of oil, I ventured to ask a question, I believe he has not answered. It was whether he had tried corona as it appears on a round conductor as an indication of the dielectric strength of oil. It seems to me that the use of corona in such a connection might possibly automatically smooth out some of the variations that appear in these curves. I believe that using corona, individual breakdowns pertaining to local irregularities in the oil, might tend to extend themselves so as to produce an average condition for the whole of the conductor and so result in a smoother curve.

W. D. A. Peaslee: In Fig. 5 is the spacing of the spheres 2 or 20 mm?

Mr. Hayden: Two mm.

Mr. Peaslee: In the table it reads two. I was wondering which one is correct, because giving the figures for both in millimeters is a startling comparison as to dielectric strength between commercial and pure benzol. It must be two.

Mr. Hayden: Two is right.

Mr. Peaslee: Were any experiments made with the heavier oil, not filtered during the process, as to whether any different result was shown than in the benzol curves. In the commercial benzol, after a considerable period of tests, the benzol was filtered, and the impurities precipitated by the disruptive discharge removed.

If that were tried, I believe, with Dr. Whitehead that this investigation is better than it looks, and that the extreme variations are not of such moment. This testing of oil is one of the most important things we have before us today in cable insulation and all other kinds of insulation. It seems to me that some of the results were tied up with the mobility of the three factors in the solution.

I would like to see some further work done on the filtering of the oil at different periods, to see if there is a section at which the rate of depreciation approaches the pure benzol curve, and in that case you will find, after the first 100 breakdowns, you are producing a constancy equal to that of air.

O. D. Wood: Designers have long realized the possibility of considerable variation in free oil spaces. For this reason, it has been the practise for years in transformers to break up with insulating barriers the oil ducts separating energized parts.

Solid insulation is not good when used alone, but oil separated by solid insulation in proper proportion gives the best cooling and breaks continuous paths, which may exist with free oil ducts or solid insulation.

The proper breaking up of the oil ducts with barriers tends to neutralize any unstable conditions that may exist in the oil. This is borne out by actual tests, an example of such tests made with oil spaces properly separated by barriers may be of interest. Free oil was separated by one, two and three insulating barriers. Tests were made with the barriers adjacent to each other, and alternating with oil spaces. The results obtained indicated a

*A. I. E. E. Journal, Vol XLI, 1922, July, p. 495.

maximum variation of less than 10 per cent above and below the average value.

It is of interest to point out here, that although under certain conditions the dielectric strength of oil may vary over a very great range, in practise it has been made the most useful and reliable insulating material that is available.

J. E. Shrader: In air electrical discharges take place much more uniformly than in oil. The reason for this, no doubt, is the greater homogeneity in air than in oil. Then in studying the breakdown in oils one should examine it for non-homogeneity. I think that the most of us who have studied oils for their electrical properties recognize the fact that most of the non-homogeneity in oils is due to moisture. One speaker has stated that at elevated temperatures uniformity of breakdown is much greater. This is due to the fact that upon heating, moisture is removed and the oil becomes more homogeneous and not only is there greater uniformity of breakdown but breakdown occurs at higher voltages. Another cause of non-homogeneity is the presence of foreign materials such as lint and dust particles. The presence of these materials is deleterious the more because they take up moisture which may thus be concentrated in the strongest part of the electrical field, thus lowering the breakdown voltage. Barriers in electrical apparatus are of benefit because they prevent the lining up of these moisture laden particles.

In making successive tests upon a sample of oil the character of the sample is altered. By each breakdown moisture and impurities are removed so that at each successive breakdown we have a different set of conditions. Hence to get any real comparison of breakdown voltages each shot should be made upon a new sample of the original oil.

F. W. Peek, Jr.: The investigation of Messrs. Hayden and Eddy is very interesting in that a great number of consecutive points were taken and that all points were recorded. In a theoretical investigation of this nature it is desirable to use electrodes for which the stresses can be calculated. For this reason the sphere gap was used. With the electrodes and spacings used in practise the variation is decidedly less. However, the interesting fact is not the extent of the variation but that there is a variation and that it follows the probability curve.

It means that from time to time a chance variation occurs in the oil between the gaps which affects the dielectric strength. This variation, whether it is due to gas, or to the lining up of particles, has a considerable range. These tests, therefore, confirm, theoretically, the long established practise of using barriers.

C. P. Steinmetz: I had the advantage of seeing these results before their publication, and also of seeing a large number of other results which have not yet been published, and which, to my mind, seem to answer several of the questions raised.

To begin with the question whether new samples should have been taken. I have seen a large number of tests made by using new samples for from 25 to 50 tests, and from the results, I have to agree with Mr. Hayden that it is impracticable to do so, because the successive samples of oil from the same supply vary so much that constant or consistent results can be derived by using one sample only, but such a very large sample, several thousand cubic centimeters, that the individual breakdowns do not appreciably affect the oil. In these tests given here in the paper, I understand, Mr. Hayden took averages at every 50 successive breakdowns. These showed that for the first two hundred or three hundred tests there is no appreciable deterioration, but the breakdown voltage remains the same and only after that number of tests does the oil deteriorate.

Now, as to the different kinds of oil: I have seen tests of different kinds of oil, heavy oil and light oil, and water-white oil, but there was no appreciable difference in the nature of the tests.

The first thing that presents itself as possible cause of the erratic performance of oil, naturally, is occluded moisture. I have seen a number of tests made to find whether the moisture has anything to do with it. For instance, a sample of oil was taken and heated several times and the oil was then filtered by passing it through a large number of layers of hot filter paper, and then it was atomized into a high vacuum, and allowed to settle there, where certainly all occluded air and moisture was evaporated, and then allowed to settle under the exclusion of air for several weeks, and then it was tested again in the same way as oil taken straight from the barrel, but it did not show any materially higher nor more constant breakdown voltage.

A very curious result is shown by the curve of pure benzol. If you notice, there is a quite rapid deterioration during the first readings, and then it comes almost to a stand still, and the deterioration is less rapid. Now, benzol deteriorates very much more rapidly than oil, and while it started perfectly transparent, after fifty tests, it was entirely opaque, but it had become more constant, and a very highly carbonized black benzol was more uniform than the pure benzol. The curve of commercial benzol shows the same. After it was filtered, and a few hundred readings had been taken, the first part showed greater variability than after it became black. It is rather curious, and seems to show after you get it deteriorated and blackened, it becomes more constant again.

F. B. Silsbee: Some time ago I had occasion to participate in some tests of transformer oil for the American Society for Testing Materials[1] in which some 2000 breakdowns were involved. These were, however, distributed over a number of different conditions and consequently do not closely parallel the present work. It is interesting to note that the average deviation of 1 shot from the mean of a group of 50, as estimated from this A. S. T. M. data, comes out as 9 per cent which is in fair agreement with the present results. The earlier data also indicated, though much less emphatically, the astonishingly slight effect of the carbon formation on the breakdown voltage of oil.

One feature of interest in the present paper is the fact that in Figs. 1 to 4 inclusive there appear occasional very low points while there is an absence of corresponding occasional high points. This would presumably cause the frequency curves of Fig. 7 to be somewhat skewed as shown in the earlier paper by the same authors. It is is to be regretted that the experimental points are not shown on the curves of Fig. 7. Is it not probable that these low points are the result of a lining up of bits of impurity so as to make abnormally long weak spots in the dielectric much as suggested by Hirobe, Ogawa and Kubo?[2] These low points are strikingly absent in the case of pure benzol and air.

W. B. Buchanan: In his preliminary paper Mr. Hayden says that the discharge current was limited by the use of resistance in the low-tension circuit so that carbonization would be reduced to a minimum. Another important point is the length of time the arc is allowed to persist after each breakdown and as the method of controlling this is not stated, the system used in the Laboratories of the Hydroelectric Power Commission may be of value.

Our regular testing equipment is provided with an overload relay in the primary circuit thus opening the circuit much more quickly than can be done by hand. The relay does not operate on incipient sparking such as occurs when fine dust, etc. is present but can be depended on to open the circuit promptly as soon as actual break down value of the oil itself is reached. The voltage control is obtained from a motor-driven potentiometer rheostat, one coil closing the circuit automatically at zero voltage, another opening it on puncture of the oil. With this equipment we believe our oil test results are more reliable than is normally obtained by hand control and from a mental summary of the results obtained the writer would say that good oil which has been in service for some time and well taken care of

1. Report of Committee D-9, A. S. T. M. on Electric Insulating Material—June 1921.

2. Hirobe, T., Ogawa, W., and Kubo, S. Report No. 25, Electrotechnical Lab., Tokyo, Japan.

may show a peak on the probability curve of the test results which would be comparable with that shown by Mr. Hayden for air. On the other hand new oil is nearly always more erratic and quite frequently the breakdown value as shown by the meter does not tell the complete story. Deductions may be made sometimes by noting the behavior of the oil itself under stress previous to breakdown as to whether the possibility of improving the oil by further filtration is promising or otherwise.

W. S. Flight:

1. *General:*

This investigation has shown (a) That provided reasonable precautions are taken in determining the breakdown voltage of air fairly consistent results may be obtained. (b) When determining the breakdown voltage of certain liquid dielectrics it is impossible to obtain anything like as consistent results as with air.

It would appear that from Hayden and Eddy's investigations and also from other published data[3], that the mechanism of breakdown of liquid dielectrics (particularly that of oil of commercial purity) is different from that of gaseous dielectrics.

2. *Theory of Breakdown of Oil:*

From an examination of the present available data relating to the electric strength of oil it would appear that oil of commercial purity may breakdown in two different ways. (a) *When Tested between Point Electrodes*: by actual puncture through the dielectric in a similar manner to gaseous dielectrics: the action of the electric field being rather to repel than to attract any impurity into the gap. (b) *When Tested between Sphere Electrodes*: by the lining up of impurities which either shorten or entirely bridge across the gap. (c) *When tested between Disk Electrodes*: by a combination of methods (a) and (b).

(3) *Experimental Evidence in Support of the above Theory:*

(a) *Breakdown of Oil between Point Electrodes*: (i) *Results reported by the Electrical Research Assn.* The data given in Table I below have been abstracted from Table I on page 702 of the "*Electrician*" for December 2, 1921.

TABLE I

Investigator	½ in. sphere gap 15 mils apart	Point gap 15 mils apart
Digby & Mellis	11.5 kv.	17.5 kv.
Everest	20.0 "	22.0 "
Peek	64.0 "	22.0 "
Hirobe	92.0 "	15.0 "

These tests on oils containing different quantities of impurities as well indicated by the sphere gap tests, showed that the results obtained with point gaps were practically uninfluenced by the impurities in the oil. (ii) *Results reported by Dr. Hirobe*: In report No. 25 of the Third Section of the Electrotechnical Laboratory of Tokyo, Dr. T. Hirobe gives a curve showing the relationship between the moisture content and the breakdown voltage of fibre-free oil tested between point and disk. During these tests it was found that for a considerable range the breakdown voltage *increased* with increase in the moisture content. An indication of the numerical value of this increase can be obtained from the result given in Table II below.

TABLE II

Effect of Moisture Content of Oil on the B. D. V. of Fibre-Free Oil, when tested in a 300-mil gap between a point and a disk

Percentage of moisture in oil	B. D. V. at air temperature	Percentage *increase in* B. D. V. over that of moisture free oil
Nil	21 kv.	Nil
0.004	25 "	19
0.008	37 "	76
0.012	45 "	114
0.020	52 "	149
0.028	52 "	149

The increase in B. D. V. with increase in moisture content is explained by Dr. Hirobe to be probably due to the following: (a) That with pointed electrodes the electric field is not uniform and consequently the moisture cannot line up between the electrodes and form conducting chains. (b) That particles of water collect around the electrodes and by changing the shape or area of the point so reduce the maximum voltage gradient between the electrodes.

(b) *Breakdown of Oil between Sphere Electrodes*: (i) *Results Reported by Dr. Hirobe*: In the same reference as given in (a), (ii), Dr. Hirobe shows a corresponding curve obtained with the same oil but with ½ in. sphere electrodes and a gap of 150 mils. Both with fibre-free oil and oil containing fibres the electric strength was found to *decrease* with increase in moisture as shown in Table III.

TABLE III

Effect of Moisture Content of Oil on the B. D. V. of Fibre-Free Oil and Oil Containing Fibres, when Tested in a 150-mil gap between ½ in. diameter spheres.

Percentage of moisture in oil	B. D. V. at air Temp.		Percentage *decrease* in B. D. V. over that of moisture free oil	
	No fibres	With fibres	No fibres	With fibres
Nil	90 kv.	35 kv.	Nil	Nil
0.004	71 "	20 "	21.0	43.0
0.008	66 "	16.5 "	26.6	53.0
0.012	64 "	16 "	29.0	54.0
0.020	62 "	15.5 "	31.0	55.8
0.028	61 "	15.5 "	32.4	55.8

The fact that the presence of fibres causes, with a definite moisture content, a greater falling off of electric strength than when the fibres are not present, is attributed by Dr. Hirobe to the following: With sphere electrodes and a comparatively short gap the electric field is fairly uniform, and when fibres were present in the oil these were observed to line up across the gap, and if of lower electric strength than the oil itself, breakdown took place at a lower voltage. When water was introduced into the oil a small percentage was apparently dissolved in the oil and caused a certain decrease in the electric strength. The greater part of the moisture however, was held in suspension in the form of minute spheres, which, due to their high surface tension, were not distorted by the electric field and so could not of themselves form conducting chains across the gap. When fibres were present in the gap, the water was absorbed by the fibres, which on bridging across the gap thereby produced a greater falling off of the breakdown voltage.

4. *Tests on Oil of Lower Purity.*

In attempting to apply the theories outlined in Section 2 above to explain the results reported by Messrs. Hayden & Eddy, it must be remembered that as these investigators' oil was first rendered as free as possible from moisture and other impurities the electric strength was considerably higher than oil of commercial purity. For example the average breakdown voltage of the oil when tested between 1-cm. spheres and with a 2-mm. gap was 55 kv. whilst the American practise in industrial work is to accept oils which have a breakdown voltage of 22 kv. when tested between 1 in. diameter disks and a 0.10-in. gap, and the British practise is to accept oils having a breakdown voltage of 22 kv. when tested between ½ in. diameter spheres and a 0.15-in. gap. It is probable that with oils of commercial purity

3. See the following:
(a) Electrical Insulating Properties of Transformer Oil, by Dr. T. Hirobe. Report No. 25 of Elec. Tech. Laboratories Tokyo, Japan.
(b) Effect of fibre on the electric strength of insulating oil, by T. A. McLaughlin, Electrician.
(c) Research on Insulating Oils by the Electrical Research Association. *Electrician*, December 2nd, 1921.

distinctly different results may be obtained, and it would appear well worth while to extend this investigation to cover oils of lower purity.

With the latter it is probable that considerably more erratic results would be obtained when the electrodes consist of a sphere, and more uniform results when the electrodes consist of a point and a sphere.

It is interesting to note that even with the comparatively pure oil employed by Hayden and Eddy it was observed that the point electrodes gave the most consistent results, and also that with the point electrodes the curves between the percentage variation from the mean and the percentage of the total number of breakdowns was symmetrical on both sides of the mean.

5. *Effect of Viscosity*:

If, during the determination of the electric strength of liquid dielectrics the conditions are such that breakdown takes place due to lining up of impurities, the freedom with which these impurities can move about in the oil should have an effect upon the breakdown voltage.

Reducing the viscosity of a liquid dielectric may affect the breakdown voltage by (a) Increasing the ease with which the impurities can line up. (b) Increasing the velocity of the circulating currents in the oil which are set up by the electrostatic stress on the liquid adjacent to the electrodes.

The writer has shown elsewhere[4] that decrease in viscosity may under certain conditions cause an increase and under other conditions a decrease in the breakdown voltage of a liquid dielectric. It is possible that the more consistent results obtained with benzol may be due to the fact that this liquid had a lower viscosity than the oil employed. To study the effect which viscosity may have in this connection, it would be interesting to have similar data to that obtained by Hayden and Eddy on transil oil at, say 90 deg. cent.

W. N. Eddy: A large majority of the questions brought up in the discussions is very well answered in the discussion of Dr. Steinmetz.

We understand Mr. Buchanan to say he has obtained breakdown data on oil that are no more erratic than our data on air. We must admit that we are inclined to question the testing methods giving such radical results. After examining the rather brief description of his testing methods we believe we at one time tried out a similar scheme and discarded it as being too insensitive.

Mr. Flight suggests that the difference shown between oil and benzol might be due to the difference in viscosity, and that this could be brought out by taking similar data on oil at 90 deg. cent. We have taken several similar sets of data on both the same and much lighter oil at 100 deg. cent. and the results while possibly a trifle more consistent than our published oil data were in no way comparable with those on benzol.

DETERMINATION OF TEMPERATURE ON ELECTRICAL APPARATUS AND CABLES IN SERVICE*

(Rutan) Niagara Falls, Ontario, June 27, 1922

E. S. Lee: Those of us who are engaged in making temperature measurements know that heat is elusive and gets away from us very easily, and we have to take due consideration of the fact that it may go from one place to another by conduction or by convection or by radiation; the measurement of temperature is therefore complex.

As Mr. Rutan said, the thermometer method is simple and convenient. We make such extensive use of the mercury thermometer in our daily life that we sometimes apply it in our engineering without knowledge of the fact that errors may exist. Differences in temperature along the thermometer stem, poor contact of the bulb with the measuring surface, broken mercury column are the most frequent sources of error. Formulas are available for emergent stem correction; their use is not always productive of accurate results. Contact errors can be eliminated if care and thought are used. Felt pads and putty both provide means for affixing thermometers. Broken mercury columns can be detected by careful inspection.

If you want to find out something concerning the accuracy of the results that you are getting from any measurement with mercury thermometers, just make a measurement and remove the thermometer completely; replace it and take another observation. Do this half a dozen times and you may find there is considerable deviation. There may be a deviation of as much as 5 degrees, even when you are trying to keep everything else constant, and you must be careful to do that.

Mr. Rutan speaks of the resistance thermometer, and, in his particular case he has not made so very much use of it. Use can be made of it in a great many installations and it is particularly convenient in that you can read the indicator directly without having to make any manipulations, the exciting voltage remaining constant. For tests where facility of reading the indication is an important factor, the resistance thermometer should be considered.

In regard to the thermocouple, what Mr. Rutan has said about its being of wide application, is very true. In connection with his acceptance tests, in order to assure himself that the wire is according to the specification, I find that he speaks of testing it up to 150 deg. cent., and that he heats it up to 100 deg. cent. for an hour to see that there are no parasitic currents generated to affect the result. I am wondering if Mr. Rutan uses rubber thermocouples at such temperatures as 100 or 150, or 200 deg. cent.? If rubber is used at these temperatures, I think you will get into trouble. If you are using a thermocouple junction which will stand these high temperatures, with rubber and cotton covered leads out in the regions where the temperatures are low, you may be all right. Leads covered with rubber only are positively detrimental.

In item 4, on page 465, I understand from what Mr. Rutan says that he takes a 50-ft. sample, winds it up, and puts it in the oven a 100 deg. cent., allowing one end to extend into the open to which an indicator is connected. I would suggest another test whereby the entire length of thermocouple is extended in the room, the ends of this thermocouple being adjacent, one being connected to an indicator. Now heat the thermocouple to any desired temperature at different points along its length. The indicator should give zero deflection if the thermocouple materials and insulation are without defect.

E. J. Rutan: Replying to Mr. Lee in regard to the use of rubber insulated thermocouple wire at 100 deg. cent. or above I wish to state that the temperature limits given were mentioned in connection with the junction temperature. The wire itself is usually in air at a much lower temperature. In cases where the wires may pass through high temperature spaces leads insulated with glass or vitreous beads are used in place of the rubber insulation.

Mr. Lee also suggested heating the wire under test at different points along the length in order to detect defects in the insulation. This method had been tried but was more time-consuming than the method outlined in the paper which gives the desired information on a full length with one test.

A METHOD OF DETERMINING RESULTANT INPUT FROM INDIVIDUAL DUTY CYCLES AND OF DETERMINING TEMPERATURE RATING (Jones)*

Niagara Falls, Ontario, June 27, 1922

V. Karapetoff: Let us take a machine shop, say with thirty identical machines, where thirty operators perform the same operation, for instance, turning a rod to a smaller diameter. Before each machine-tool raw parts are piled up, and when the

4. See Spark Over Voltage Through Oil, *Beama Journal*, Feb.-March, 1922.

*A. I. E. E. Journal, Vol. XLI, 1922, June, p. 464.

*A. I. E. E. Journal, Vol. XLI, 1922, May, p. 329.

whistle blows in the morning these men begin operations. Each one takes a piece, fastens it in the lathe, runs the cut, unfastens the piece and puts it back on another tray. Then he takes again another piece and performs the same operation. But all operators do not start at the same instant. Mr. Jones assumes that each machine is driven by an individual motor and as soon as the operation is completed the motor is stopped. Because the men do not start at the same instant, there is some phase displacement in the cycles, and Mr. Jones' problem is to evaluate, by the theory of probabilities, the demand on the power plant under those conditions.

In the case of a very large number of identical machines, the demand on the generating equipment cannot be very different from the average current; that is, if you superimpose those numerous duty cycles, you get practically a horizontal line. So that, in my estimation, with a large number of machines this whole complicated method of probabilities is unnecessary. Look at the tables in the paper. The coefficients in the binomial series are figured out to several places of decimals, to estimate the demand on a power plant. The author performs complete computations for the current, and shows in the end that according to the theory of probabilities the average current is 300 amperes. But the ordinary, common sense average is also exactly 300 amperes. Then, in another example, the difference between the current computed according to the formula of probabilities and the ordinary average is something like 2 amperes. One surely cannot estimate the equipment of an industrial plant down to 2 or 3 amperes.

On the other hand, let us assume that the number of motors is very small, for instance, in an office building with four elevators. Let it be required to estimate the curve of the power demand with any arbitrary time distribution of starting of these elevators. I doubt again, in this extreme case the advisability of applying the theory of probabilities. The theory of probabilities tells you what might happen with a large number of identical objects or events, the most probable combination is very likely to happen; but with only four objects such is not the case. It would not be safe to figure on the most probable curve of power demanded with four elevators starting at random. Now and then at least three of them may start at the same time, and even though this may not happen very often, it may mean an interruption of the service.

What we really want is not the most probable curve, but the danger curve of demand at starting; about this curve the theory of probabilities will give you no information whatever. Your ordinary common sense should tell you what to provide for. Thus, it seems as if we would have to eliminate from the scope of the paper both a large number of motors and a small number of motors.

The theory of probabilities is also not needed to compute the total kw-hr. per year. If I know the duty cycle of a motor, the number of such cycles per hour, and the number of machines, I can readily compute the total demand.

Mr. Jones computes separately the most probable current when a motor is running (with the starting rheostat out) and from it he determines the r. m. s. current for that part of the cycle; that is, the current that will give the same heating in the conductors as the actual current. Then he takes the starting period and figures out the r. m. s. starting current, over and above the running current. Finally he adds arithmetically those two r. m. s. currents; this last procedure is wrong. Since the heating is proportional to the square of the current, one cannot add effective currents arithmetically. It is necessary to take a square root of the sum of the squares. In the author's example, instead of a current of 507 amperes, I get only 372 amperes. However, when the theory of probabilities is used, it is not even permissible to take the sum of the squares: it is necessary to figure out the individual total currents, and to add their squares, each multiplied by the relative duration of time.

F. W. Owens: Mr. Jones' paper is a welcome innovation in the treatment of problems in electrical design. The introduction of new methods of attacking old problems is always stimulating and there is no doubt much more opportunity for the use in engineering practise of the methods of the theory of probabilities which have been of great service in the consideration of problems involving the treatment of mass data.

In applying new methods, however, the early attempts often lose sight of some of the niceties of the methods and may apparently lead to wrong results, or to a misinterpretation of results.

In the present paper of Mr. Jones, the problem considered, in essence, is that of designing the installation of generators and equipment, including protective devices, for furnishing current to a number of machines having regular duty cycles of known character, say a starting period drawing a heavy current, then an ordinary running period drawing less current, followed perhaps by an idle period. These characteristics of an individual machine being known, but the separate machines operating at random, it is necessary to estimate the amount of generating equipment and its character, and the nature and size of the various protective devices.

The *total* demand for current may readily be estimated without any elaborate methods, since it is simply the product of the average amount drawn by one machine and the number of machines.

More elaborate methods are necessary, however in considering such questions as the total size of generating plant and size of protective devices. Mr. Jones does not treat the first of these questions directly, although the methods of probabilities are very likely to be of much service there.

The most interesting part of Mr. Jones paper rests upon the following assumption which does not seem to be made sufficiently prominent. If a variable current flows in a circuit, the result is the same if the various periods in which the current has a given value are grouped together instead of occurring at different times. Mr. Jones uses this assumption only in regard to total input and heating effects. As far as total current is concerned, the assumption is obviously true. In the case of heating phenomena, it is true as far as the amount of heat produced is concerned, for this is proportional (for a circuit with fixed characteristics) to the square of the current multiplied by the time. However the disposal of this heat is vitally affected by the order in which the various sized currents flow, as well as their magnitudes, particularly if fuses, conduction of heat, etc., are concerned. I do not wish to discuss this phase of the matter, except to make clear the nature of the assumption, but this would have to be considered carefully.

In treating the question of "heat input" as well as total current input, Mr. Jones uses the concept familiar to the actuary as Mathematical Expectation. In applying this to the total input he proceeds correctly, although the complicated process is not necessary, but in his treatment of the heat input, or r. m. s. total input, he makes a serious error of principle, which I shall try to point out. The current input is divided into two parts in his argument, starting current and ordinary running current. These are treated independently, each as if the other were not present, and the results are added numerically. This leads to the correct result for the current itself, but to a wrong result except when only one size current is treated. I will first show this in a very simple problem, then in the illustration Mr. Jones uses in his paper.

Consider two machines each with the following duty cycle. The machine uses 200 amperes for one second, then 100 amperes for three seconds, then is idle for two seconds, then repeats. For each machine, at any time, the probability that it is starting is 1/6, that it is running light is 3/6, and that it is idle is 2/6

Thinking of the starting currents and running currents as distinct, we would say with Mr. Jones that the probability that a machine is running is 4/6, that it is idle is 2/6. We would then have a probability (4/6) (4/6) = 16/36 that both machines are running, 2 (4/6) (2/6) = 16/36 that one machine is running and that the other is idle, (2/6) (2/6) = 4/36 that both machines are idle. The respective currents flowing are 200, 100 and 0 amperes. For the root mean square running current we would have

$$\sqrt{\frac{16}{36}(200)^2 + \frac{16}{36}(100)^2 + \frac{4}{36}(0)} = 149 \text{ amperes}$$

For the starting currents, thought of as extra currents, for each machine the probability of extra current flowing is 1/6, the probability of its not flowing is 5/6. The probability that both machines have extra current flowing is (1/6) (1/6) = 1/36. The probability that extra current is flowing in one machine and no extra current in the other is 2 (1/6) (5/6) = 10/36. The probability that neither machine is drawing extra current is (5/6) (5/6) = 25/36. The total amount of extra current drawn in the three cases is 200, 100 and 0 amperes, respectively. We have then for the r. m. s. of the extra starting current

$$\sqrt{\frac{1}{36}(200)^2 + \frac{10}{36}(100)^2 + \frac{25}{36}(0)} = 62 \text{ amperes}$$

Adding, we would have for total r. m. s. current 149 plus 62 = 211 amperes, which is the result of following Mr. Jones' process.

The correct procedure is as follows, since there is no distinction between ordinary running current and starting currents, and the *sum* should be squared, rather than treating the results separately. There are six different possibilities, according to what the motors are doing. If we use (a b c) to mean a motors are starting, b motors are running steadily, c motors idle, these cases are (2 0 0), (0 2 0), (0 0 2), (1 1 0), (1 0 1), (0 1 1). The respective probabilities are (1/6) (1/6), (3/6) (3/6), (2/6) (2/6), 2 (1/6) (3/6), 2 (1/6) (2/6), 2 (2/6) (3/6). The respective currents are 400, 200, 0, 300, 200, 100 amperes. Hence for the root mean square input we should have

$$\sqrt{\frac{1}{36}(400)^2 + \frac{9}{36}(200)^2 + \left(\frac{4}{36}\right)(0) + \frac{6}{36}(300)^2 + \frac{4}{36}(200)^2 + \frac{12}{36}(100)^2} = 193 \text{ amperes}$$

instead of the 211 amperes obtained by the wrong process.

In general, if we have N machines, each with a probability p_1 of a current i_1, probability p_2 of a current i_2, . . . probability p_n of a current i_n, the probability of any given combination of k_1 machines drawing a current i_1, k_2 machines drawing current i_2, etc., is obtained from the term containing $p_1^{k1}\, p_2^{k2}\, p_3^{k3}$ . . . in the expansion of $(p_1 + p_2 + p_3 + \ldots p_n)^n$.
(See Hall and Knight, Higher Algebra, or any standard book on Probabilities).

If we apply this to the problem given by Mr. Jones, in which we have six machines each with a duty cycle of 20 seconds, using 200 amperes for 5 seconds, then 100 amperes for 5 seconds, then idle 10 seconds, the work may be tabulated as follows:

Number of motors drawing 200	100	0	$p = 1/4$, $q = 1/4$, $r = 1/2$ Probability π of the combination	Current $\frac{i}{100}$	$\frac{i^2}{10{,}000}$	$\frac{4^6(\pi\, i^2)}{10{,}000}$
6	0	0	$p^6 = 1/4^6$	12	144	144
5	1	0	$6\,p^5 q = 6/4^6$	11	121	726
4	2	0	$15\,p^4 q^2 = 15/4^6$	10	100	1500
3	3	0	$20\,p^3 q^3 = 20/4^6$	9	81	1620
2	4	0	$15\,p^2 q^4 = 15/4^6$	8	64	960
1	5	0	$6\,p\,q^5 = 6/4^6$	7	49	294
0	6	0	$q^6 = 1/4^6$	6	36	36
5	0	1	$6\,p^5 r = 12/4^6$	10	100	1200
4	1	1	$30\,p^4 q\,r = 60/4^6$	9	81	4860
3	2	1	$60\,p^3 q^2 r = 120/4^6$	8	64	7680
2	3	1	$60\,p^2 q^3 r = 120/4^6$	7	49	5880
1	4	1	$30\,p\,q^4 r = 60/4^6$	6	36	2160
0	5	1	$6\,q^5 r = 12/4^6$	5	25	300
4	0	2	$15\,p^4 r^2 = 60/4^6$	8	64	3840
3	1	2	$60\,p^3 q\,r^2 = 240/4^6$	7	49	11,760
2	2	2	$90\,p^2 q^2 r^2 = 360/4^6$	6	36	12,960
1	3	2	$60\,p\,q^3 r^2 = 240/4^6$	5	25	6000
0	4	2	$15\,q^4 r^2 = 60/4^6$	4	16	960
3	0	3	$20\,p^3 r^3 = 160/4^6$	6	36	5760
2	1	3	$60\,p^2 q\,r^3 = 480/4^6$	5	25	12,000
1	2	3	$60\,p\,q^2 r^3 = 480/4^6$	4	16	7680
0	3	3	$20\,q^3 r^3 = 160/4^6$	3	9	1440
2	0	4	$15\,p^2 r^4 = 240/4^6$	4	16	3840
1	1	4	$30\,p\,q\,r^4 = 480/4^6$	3	9	4320
0	2	4	$15\,p\,q^2 r^4 = 240/4^6$	2	4	960
1	0	5	$6\,p\,r^5 = 192/4^6$	2	4	768
0	1	5	$6\,q\,r^5 = 192/4^6$	1	1	192
0	0	6	$r^6 = 64/4^6$	0	0	0
						99,840

For root-mean-square current we have

$$\sqrt{\left(\frac{99{,}840}{4^6}\right)(10{,}000)} = 493.+$$

By Mr. Jones' method, the result was 507 amperes instead of the correct 493—remarkably close for a faulty process.

It is obvious that the numerical computations become rapidly more difficult as the number of machines, or number of different sized currents is increased. The tables in Mr. Jones paper do not help in this as they are of no value when the number of currents not zero is two or more.

It should further be remarked that those unfamiliar with the subject of probabilities should be careful not to understand that Mr. Jones means actually to predict what currents will really flow in the circuits involved at any time, but that the figures are to be understood as averages to be expected. Neither the theory of probabilities nor any thing else can predict the actual happenings, except in this sense of averages, although it can state what is most likely to happen, and the degree of probability of either the most likely, or some other, occurrence.

Bassett Jones: I regret that the error pointed out by V. Karapetoff and F. W. Owens exists in the method. The same error has been recently pointed out to me from two other sources, also with the remark that the error in result is small. As a matter of fact this error has not been picked up in any actual case while the method has been in use during the past several years. In other words, measured results have always compared so closely with calculated results that no reason for doubt developed.

The method has its limits, of course, but a method with limits is better than no method at all. Probabilities is merely a way of guessing intelligently. By its use, guesses have proved to be nearly correct. Without it, the margin of deviation between the guess and the actuality in many cases, has proved to be considerable.

The necessary correction is quite obvious. It is in the approximation used (See Figs. 1 and 2.) The running current i should be taken for the time T_r-T_s'. The starting current,

I_m, and *not* $I_P = I_m - i$, should be taken for the time T_s'. In Fig. 3, take i for the time $T_r - T_s$, I_s for the time T_s, and I_m for the time T_s'. In other words, the proper divisions of the duty cycles are vertical, *not* horizontal.

Then, in Fig. 1, $p_r = T_r - T'_s/T$, $p_s = T_s'/T$, and similarly for Figs 2, and 3.

The calculations performed exactly as directed with these changes, give the correct r. m. s. values. The average values are the same with the correct and the incorrect method.

I am sorry that Mr. Karapetoff's doubts as to the value of the method as a whole are not borne out by actual experience. It has been used to determine the probable average, and probable frequency and amount of peaks for four elevators. We have not heard of any shut-downs due to the wrong selection of either fuses or circuit breakers. It has been used to determine the load distribution for 20 elevators—not all of the same capacity, nor on the same service. Here again, no shutdowns have been reported. And because the method proved useful in this case, the tables were included up to $n = 20$.

I believe the method, as applied to averages, is used in life insurance when n considerably exceeds 20, say a million or more, and many millions of dollars are invested accordingly. Surely the probable starting and stopping of a motor is a certainty compared to the probable period of a man's life.

This does not mean that the method should be used when n is large. Then the more approximate method given by me in "Standardized Flexible Distributing Systems in Industrial Plants" is available, all as pointed out in the paper.

Let me add that the description of the method looks more complicated than it actually turns out to be in practise. Much of it can be graphed for ready reference.

CONTROL OF GASEOUS CONDUCTION*

(Bush and Smith) Niagara Falls, Ontario, June 27, 1922

C. P. Steinmetz: This paper is interesting in the deductions you draw from it, because the statement made that a short gas path will not carry a discharge at voltages which will go over a much longer gas path, is rather in contradiction of our present ideas of the nature of breakdown in gases as determined by constant breakdown gradient.

This paper thus throws some doubt on our present explanations of disruptive phenomena in gases as determined by a constant breakdown gradient and energy distance.

I understand that the author had a pressure of three millimeters of mercury, that is about 1/250 atmosphere. This, reduced to the atmospheric pressure by proportionality, gives a very short gap and such a gap should hold a high voltage.

The whole subject is rather interesting theoretically from our present conception of the nature of breakdown of gases, and the matter is worthy of further investigation, since it is rather in line with many data and much information which has been accumulated in the last few years, which throws some doubt on many of our conceptions of dielectric breakdown and reopens the question of the mechanism of the breakdown of our insulating materials, and Messrs. Hayden and Eddy have shown that this may apply even to gases.

J. B. Whitehead: One of the most noticeable characteristics of this rectifying tube is that it has no hot filament, simply a rectification occurring between two plain electrodes. It is well known, at least to those whose business it is to make themselves familiar with the theory of the ionization of gases, that the positive and negative ions of a gas have different values of mobility, or the rapidity with which they will move and diffuse. At these pressures, I suppose, we have a preponderance of simple electrons or negative ions, over the positive ion, *i. e.* the residual of the molecule after it loses a negative ion.

Of course, these two types of ions have widely different values of mobility, consequently it does not appear that we have here the ordinary phenomenon of the breakdown of gases as discussed by Dr. Steinmetz, but that we have the simple generation of ions, by the natural process of ionization, and that the uni-directional conductivity of the tube, results from the difference in the mobility of the two types of ion; in other words, in sustained action, the lighter negative electrons are drained away, leaving the excess of positive ions, and the presence of that excess of positive ions must necessarily result in a uni-directional conductivity.

J. E. Shrader: The experiment described by Messrs. Bush and Smith is the noted experiment described by J. J. Thomson where the electric discharge at diminished pressures takes place through a long path rather than the alternative shorter path. The principle involved is that of ionization by collision. To acquire sufficient velocity to produce other ions by collision the path should be sufficiently long before impact—with gas molecules. When this velocity is sufficiently great more ions are formed by collision with the gas molecules and these ions so formed may acquire sufficiently high velocity to produce other ions.

Messrs Bush and Smith have here well utilized the phenomenon of ionization by collision.

C. P. Steinmetz: I might answer one point Dr. Whitehead brought up. I do not see why the mechanism of breakdown of several cm. gap length at atmospheric pressure should be any different from that of minute gaps with higher vacuum.

As regards the uni-directional feature of the conductivity that exists in long air gaps, this was first investigated by Mr. Peek with different electrodes, but it is only in the last year that high and constant uni-directional voltages have become available for investigation.

Mr. Hayden has made a number of interesting tests showing the conductivity between the point and plate, at voltages of 100,000, with distances of many centimeters. This conductivity is undirectional, so much so that the disruptive strength of the needle point and plate or large sphere with one direction of voltage is more than twice what it is with the other. This can be used to rectify alternating voltages and we are using such a plate and needle point gap with large condenser to produce high uni-directional voltages.

So it seems we get phenomena at these high voltages and large gaps similar to those we are known to get in minute gaps at high vacuua.

V. Bush: The experiment of the long and short paths, which I believe was due to Hittorf, shows that in general the discharge prefers a long path to a short one, when the short path is short under the definition of the paper, and the long path is not purposely suppressed. The point I want to emphasize is the extent of this preference, which has not been generally realized. The preference may readily be so strong that, if the long path is suppressed, the short path will not break down at, say, 10,000 volts, whereas, the long path would if allowed break down at 300 volts.

As to another point, brought up by Dr. Whitehead: Of course, if we attempt to apply this principle at atmospheric pressures, the distances involved are about 1/10,000 of a centimeter as Dr. Steinmetz points out. With the low pressures, we have to deal almost entirely with positive ions and electrons, whereas at the higher pressures, the effect of the negative ions is ordinarily also important. It is not at all settled that this would still be true with very close separations.

There is one further point. I would like to distinguish this apparatus from the rectifier which depends simply on dissymmetry of electrodes, and which thus depends for its action on the difference in breakdown voltage in the two directions,—such as the point and plate and the corona rectifier. In the non magnetic type of this tube the breakdown voltage in the two directions is approximately the same, but the characteristics in the two directions are very widely different.

*A. I. E. E. Journal, Vol. XLI 1922, September, p. 627

HIGHER STEAM PRESSURES OR PULVERIZED COAL*

(Scheffler) Niagara Falls, Ontario, June 28, 1922

Philip Torchio: I would like to ask Mr. Scheffler why contrast higher steam pressures against pulverized coal. Why not both? What is inconsistent between the two? The pulverized coal situation as affecting large cities is mostly a question of improving means to handle the ashes that come from the stacks. Until that problem has been definitely solved, it would be practically inadvisable to attempt, in a densely populated district, to install on a very large scale a system of coal burning that would scatter a considerable amount of ashes in the territory surrounding the station.

The question of using higher steam pressures is of vital importance. I do not know that the figures of cost of present standard pressure boilers and piping would be much exceeded if we had a fully developed system of high pressure machinery, and the boiler makers would standardize production on higher pressures that they have been doing. In that event, the increased cost of the equipment might not be as great as shown by the figures of Mr. Scheffler.

It seems to me that the difference in saving of less than five per cent between low pressure and high pressure is probably somewhat low, and that a larger saving would be realized in practise.

Abroad, there is now a station operating at 450 lb. pressure and 750 deg. steam temperature. We should look to the performance of that station with a great deal of interest.

Wm. McClellan: I have been in contact with pulverized fuel a great deal, and the burning of it at the mine. I could not quite see the point involved in the title of the paper "Higher Steam Pressures or Pulverized Coal." If there is any economy in high steam pressures, the economy is there, and if there is any economy in pulverized fuel, it is there.

My idea, without looking into the question of ashes, is that it can be cared for, and with some profit. So far as blowing out the ashes is concerned, that is not a vital feature of the problem. If you choose coal at $5.00 a ton, you may come out all right. There are lots of plants in this country which will be built to order, using cheap fuel.

Of course, if you have not sufficient load factor to work out all the advantages of economy, and if you do not use the more efficient methods long enough, you do not derive the greatest benefit, but in any event, it is no more expensive, and if it is no more expensive, this particular point vanishes. I do not quite see the distinction, first of all, between the antithesis which has been set up in the title of the paper, nor do I see that any one particular problem with a fixed coal price, and with a high one, without much discussion of the load factor, answers the question very definitely.

F. A. Scheffler: The President answered Mr. Torchio's question so far as the ash disposal from the stacks is concerned, but this is not an important part of the proposition. If the location of the plant is such that the fine ash coming out of the stacks is disturbing to the surrounding country, prevention can be taken care of more readily and with less expense than would be the case with cinders coming from stokers from the stacks.

The title of this paper probably should have been "Higher Steam Pressures and Pulverized Coal" as it is a little misleading as it now stands. The writer in dealing with this question had more particularly in mind the possibility of equipping low-pressure plants in such a way that they would compare favorably with the more expensive and higher pressure plants, even showing better efficiency with lower operating expenses. This is clearly shown in Column 4, page 347 as that column deals with a plant which was fired with pulverized coal, using higher steam pressures.

In order to really appreciate and understand fully the principal features developed in this paper, it is necessary to read it in toto carefully and I judge, from the remarks made by the President, as well as the other speakers in the discussion, that they have not done this, otherwise they would have noted that the answers to the questions they brought up were practically taken care of in the paper.

*A. I. E. E. Journal, Vol. XLI, 1922, May, p. 346.

QUEENSTON—CHIPPEWA DEVELOPMENT OF THE HYDROELECTRIC POWER COMMISSION OF ONTARIO* (Gaby); DESCRIPTION OF THE 45,000 Kv-a. QUEENSTON GENERATORS** (Barns and Bowness); DESIGN OF 45,000 Kv-a. GENERATORS, QUEENSTON PLANT† (McCarty and Hart); FEATURES OF MAIN POWER HOUSE TRANSFORMERS FOR QUEENSTON PLANT‡ (Price and Skinner).

Niagara Falls, Ontario, June 27, 1922

B. A. Behrend: It is instructive to note in connection with the design and construction of these large water-wheel generators installed as Niagara Falls, that the earliest units, which were rated as 5000-h.p. units, and which operated at 250 rev. per min., installed at the powerhouse of the Cataract Construction Company, as it was then called, were made with externally revolving fields, of the "umbrella" type. The field ring consisted of a large nickel steel forging, against which the solid pole pieces were bolted.

The speed of 250 rev. per min. was retained for all units from the earliest date of installation up to 1907, when the new units installed at the powerhouse of the Niagara Falls Hydraulic Power & Manufacturing Company's plant were projected with a capacity of 7500 kw. at 300 rev. per min.

Following the precedent, the first unit of this type was designed by the speaker with a nickel steel rotor, and a full description of this generator was given in the A. I. E. E. Transactions of June 1908. During the over-speed test, the first generator furnished to the Niagara Falls Hydraulic Power & Manufacturing Company was totally destroyed, the wreck appearing similar to the recent wreck of the 15,000 kw. generator at the Ontario Power Company's plant. The generator which was destroyed at the latter plant was designed and built by another manufacturer, with a cast steel rotor.

A careful examination of the fractures of the nickel steel forgings and exhaustive tests convinced me that large forgings of any kind are unreliable. They are subject to internal stresses, which are unknown, and which could be relieved only by thorough annealing, but the annealing process itself is inimical to the molecular formation of alloyed steels, even if it were possible uniformly to distribute the heat of the annealing furnace through all parts of a large mass of steel. It must be remembered in this connection, that it is customary for pieces to be heat treated to be supplied with holes, if possible, so that uniform penetration of heat can be secured. Such center holes are not practicable in electric generators, as the removal of the metal in the center leads to the doubling of the stress, on account of the redistribution of radial and tangential stresses, resulting in tangential stresses only. This matter was discussed by me in 1917 at Philadelphia, and is recorded in the A. I. E. E. Transactions, Vol. 36, p. 883. The speaker is firmly convinced from vast experience, extending over more than a score of years, that the use of large steel forgings is to be deprecated, and that the safest construction can be obtained by discarding totally these large forgings, and using steel plate construction instead.

The first large generating unit operating at 750 rev. per min., and generating about 10,000 kw. was designed by the speaker in 1904, and built by the Bullock Electric Manufacturing Company for the Brooklyn Rapid Transit Company. The

*A. I. E. E. Journal, Vol. XLI, 1922, July, p. 508.
**A. I. E. E. Journal, Vol. XLI, 1922, June, p. 459.
†A. I. E. E. Journal, Vol. XLI, 1922, September, p. 698.
‡A. I. E. E. Journal, Vol. XLI, 1922, June, p. 452.

modern designs of steel plate rotors differ very little from this earliest prototype. Where it is possible to use a shaft, the plates are made with holes, but where it is not possible to use a shaft, the plates are bolted together with through-bolts. The journal ends are fastened to the rotors in a manner first shown to be most effective by Delaval, in his early steam turbines. The construction is now used generally elsewhere, and has been found thoroughly reliable.

The thirteen generators now operating at the powerhouse where the 7500 kw., 300 rev. per min. generator was installed in 1908, have been designed with plate rotors, the plates being made of ordinary open hearth-carbon steel, carefully heat treated, so that the steel is thoroughly ductile. Samples from these plates, which are a little over two inches thick, have been bent cold flat through an angle of 360 deg. without showing seams or fractures on the outside.

B. T. McCormick: About fifteen years ago the companies manufacturing wheel type generators paid very scant attention to the stresses at overspeed and the possibility of the destruction of a machine as a result of a run-away. Suddenly a machine flew to pieces. This was soon followed by a number of similar accidents in different parts of the country and served to awaken the manufacturers to a realization of a serious weakness in their designs and led them to make a close study of the stresses involved, and the suitability of different materials.

The design of a machine to safely stand a run-away involves two main issues; to determine the stresses accurately, and to obtain a suitable material, the strength of which is definitely known.

The method of calculation must give a true measure of the stresses actually induced. If there is any doubt as to the accuracy of the method, the error should at least be on the safe side. Many of the stresses, on careful consideration, are found to be of a much more complicated nature than was first supposed, and of far greater magnitude. Stresses that at first seemed to be simple tension are really composed of a bending moment, a shear and a tension combined.

The material must be one of uniformly good structure throughout; one that is free from local weaknesses. To know that the material is uniform and to be able to rely on it, is even more important than very high elastic limit.

Rotors built of rolled steel disks of boiler plate mounted on the shaft have been found very satisfactory; also spiders composed of several steel castings side by side. If the castings are properly annealed and enough test pieces are obtained from various parts of the structure, as an index to its strength and uniformity, this construction is very reliable. For uniformity of structure there is no doubt that the laminated field ring is the most reliable. Such a structure is so finely divided that if any weakness exists, it will be so localized that it cannot affect the strength of the ring as a whole. This ring is usually mounted on a cast steel spider and care must be taken that the expansion of the ring at overspeed does not overstress either the arms or the dove-tails of the spider, furthermore, the design must be such that expansion at overspeed does not cause it to become loose on the spider.

W. J. Foster: I agree with Mr. Behrend that it is very important that the castings for the steel forgings be selected and tested carefully. Mr. McCormick has just remarked that about fourteen years ago there was an epidemic of machines flying to pieces. That is rather news to me, although I ought to know about such cases. I do remember happenings in two or three places, one of which our Chairman has referred to. Others occurred on the Pacific Coast, about the same time.

In connection with the idea of the last speaker, who mentioned the fact that the laminations are built up, a great number of them, so that if one is weak, the situation can be saved by its neighbors, I desire to call attention to the fact that the same principle has been carried through the designs of rotors of the multiple wheel type.

I desire to state that certain plate rotors for generators of high centrifugal stresses, involved much study and the testing of a model in the laboratory to guard against such troubles as opening at the shaft on the inner edge of the disk, a trouble which was encountered about that time in the construction of certain steam turbines. In the case of these generators a satisfactory design was obtained by cutting out holes in such manner as to leave material of the proper section to stretch sufficiently to prevent the trouble that would otherwise start at the shaft. The point I wish to make is that there are problems involved in plate construction, as well as in castings, and it is well, as Mr. Behrend has pointed out, to spare no pains to select the proper construction. Often castings should not be used but a plate or laminated rotor.

R. B. Williamson: A prominent feature of the two Queenston generators is the large fly-wheel effect as compared with other machines of comparable size. The fly-wheel effect of 21,000,000 lb. ft.^{2} is much larger relatively than that of the 32,500-kv-a. machines in the No. 3 plant of the Niagara Falls Power Company. The latter generators operate at 150 rev. per min. and have a fly-wheel effect of approximately 10,000,000 to 12,000,000. Thus taking into account the relative outputs and speeds in the two cases the Queenston machines have relatively about twice as much fly-wheel effect as the 32,500-kv-a. units.

The amount of fly-wheel effect to be put into a generator is something that must be determined for each case, taking into account the hydraulic conditions. The fact remains, however, that fly-wheel effects are frequently specified that are very much higher than the normal design of the generator would give. In order to obtain these large fly-wheel effects there has been a tendency in some cases to build generators on a larger diameter of rotor than was necessary from the standpoint of electrical design. This makes it more difficult to take care of overspeed stresses and has a decided bearing on the question of rotor construction.

While it is true that cast steel and forged steel rotors have failed in some instances, it is also true that there have been failures of laminated rotors. Not only must the materials be properly selected for a given case but the mechanical design must be such that the allowable stresses for the given material will not be exceeded. In the case of very large machines, a cast steel rotor has the advantage that it can usually be put together and tested for overspeed at the factory, after which it can be disassembled for shipment. With a large laminated rim this would necessitate stacking and unstacking and the test would be of doubtful value. It is true that there have been some accidents with cast steel and other types of rotor but if care is taken to design the rotor so that the stresses at overspeed are kept to within half the elastic limit of the material and the form of the castings made, in consultation with the steel founder, so that the finished product will be sound, thoroughly annealed and free from shrinkage strains, there is no reason why entirely safe rotors cannot be made; in fact very large numbers of them have been made and have been in successful operation for years.

F. D. Newbury: In two papers describing similar generators it is interesting to observe the differences in design and construction; in other words, how different designers have met the same problem.

The major difference in construction is found in the rotor material. In the generator described by McCarty and Hart, the rotor wheel (to which the poles are attached) consists of a single relatively light steel casting consisting of a hub and arms but without a rim. The rim is built up of 1/16 inch sheet steel punchings. In the generator described by Barns and Bowness the rotating part in made up of seven cast steel wheels placed one over the other on the shaft. It would be impossible to obtain a single satisfactory steel casting for the entire rotor. Barns and Bowness have used steel castings but have subdivided the rotor into as many castings as they considered necessary to secure sound castings. McCarty and Hart have abandoned the cast material entirely (so far as the rim is concerned) and have re-

placed it by a laminated construction that eliminates the question of unreliability. The laminated rim requires more material (on account of the radial joints in the rim) and more labor, but these are offset, to some extent, by the lower cost of sheet material as compared with castings. In the present case, however, the flywheel effect specified for turbine speed regulation required two additional cast steel sections in the Barns-Bowness design so that in this case, the laminated construction has an advantage, not only in potential reliability, but in rotor cost.

A second difference is found in the type of coil bracing. In one generator the outer layer of coil ends is roped to two rings; in the other, both layers of coils are bolted to cast iron brackets. The generators also differ in type of coil insulation. In the generator described by McCarty and Hart the straight parts of the coils (embedded in the core) are encased in a rigid mica wrapper while the exposed coil ends are insulated with a flexible bond between wires and a flexible tape insulation. The other generator has a flexible tape insulation throughout the entire coil.

In one generator the upper supporting bracket is cast steel and in the other cast iron. The advantage of cast steel is greater strength permitting the use of a relatively shallow structure. However, the necessity for small deflection limits the stress in cast steel to a low value so that full advantage of the greater strength of cast steel cannot be taken. Moreover, cast steel is more expensive per pound and is considerably more difficult to handle in the foundry. There is more liklihood of defective castings and the greater chance of porosity that will lead to oil leakage from the thrust bearing pot.

O. D. Wood: There is one point in the paper on transformers that is not entirely clear, namely, the bracing of the winding against vertical forces resulting from possible displacement.

It is known that in any coil arrangement, if the magnetic axes do not coincide there exists a force tending to slide one coil or a portion of a coil with respect to the other winding. Thus, if concentric cylindrical coils are not symmetrically arranged, one coil tends to slide with respect to the other, and must be braced against such movement. Bracing is provided to guard against such a movement in concentric windings.

In interleaved windings, if the coils are not symmetrical there will exist a force tending to displace the coils as a whole or portions of the coil with respect to one another.

If the coils are circular this force is resisted by the tensile strength of the conductor because the coil is of circular section.

If the coils are not circular, but rectangular, as in the shell type, this force tends to blow out one coil and to collapse the other coil towards the core. Such a force is resisted by the iron on the coil legs, but if there is no bracing on the coil ends against movement away from the core, this force will tend to cause one of the coils to become semi-circular and to collapse the other on the bracing against the core. It would seem that it is practically impossible to obtain absolute coincidence of magnetic centers even with coils of the same dimensions, but it should be much more difficult in high-voltage transformers of the interleaved style where the primary and secondary coils are usually of different dimension. In fact, it is hard to determine in such unsymmetrical coils where the magnetic center is, so that it can be stated with some degree of assurance that there will always exist a force tending to distort the coils.

Furthermore, in any event where the coils are of different dimensions there exists a force on the wider coil tending to distort it due to the curvature of the leakage flux, *i. e.* the leakage flux is not in the straight line through the leakage gaps, but curves away and some of the flux passes through the outside turns of the coil.

The analysis on page 455 regarding the effect of opposite coil ends, shown in Figures 7A and B, should be influenced by the modifying effect of the core. Under absolute short circuit the full core flux passes through the leakage gaps, yet this flux moves into the core at every coil group, and therefore modifies the condition outlined in these figures.

W. M. Dann: It seems only a few years ago that someone made the prediction that we should have transformer banks with a rating of 50,000 kv-a., and now we have them at Queenston, and they are used on a low frequency which makes them physically much larger than they would be if used on 60 cycles. In Pittsburgh, there are banks of transformers with a rating of 70,000 kv-a. in operation, but they are somewhat smaller than Queenston transformers, because they are used on 60 cycles.

Transformers of this capacity are simply an extension in size over those that have gone before, and the problems of how to insulate them and how to cool them, and how to make them strong enough mechanically to be unharmed by the mechanical forces due to short circuits are bigger problems, but problems of the same kind that have been solved with smaller units.

Insulation troubles in general are rare and generally speaking the manufacturers are ready to insulate their transformers for any possible commercial voltage. The problem of carrying off the heat from the windings in a big transformer is not particularly simple, but it is a problem which is being successfully solved. The efficiency of these Queenston transformers is very high, slightly under 99 per cent at full load, and yet this means losses of about 175 kw. in the transformer. Most of this loss is in the windings. This means that the construction must include an efficient system of ducts to carry this heat away to avoid an abnormal temperature rise at any point. An illustration used in the paper shows a system of ducts which permit the oil to flow vertically upward, which is its natural direction. The curved strips allow the oil to come into contact with every conductor in the coil. The ribbed spacers at the tops of the coils create an open construction which undoubtedly is an important factor in reducing the temperature of the windings at these points which are naturally the hottest parts of the windings.

Perhaps the most important problem with these big transformers is to make them strong enough to withstand the mechanical forces which are present in the windings due to the action of the leakage field on the conductors. There are a good many ampere turns in transformers as big as these, even with only the normal full-load current flowing and the mechanical forces are going to be present as long as we have leakage. The mechanical forces at full load would not be negligible if they were not distributed over quite an area so that the forces in pounds per square inch are low. It is under abnormal conditions such as at the time of short circuit that these mechanical forces become formidable.

This feature of the design of large transformers calls for the greatest care on the part of the designer. As I said before, the mechanical forces are going to be present as long as we have leakage fields cutting current carrying conductors and they will appear as a stress in the materials. This is independent of what kind of construction is used. In a transformer with interleaved coils for instance they will appear, in a shell-type transformer, in the form of bending moments at the tops and bottom of the coils and in a core-type as a crushing force and they must be restrained by the coil bracings.

In a core-type transformer with concentric coils they appear as a tensile strain on the conductors and they must be kept within the tensile strength of the copper.

The vertical components spoken of by the authors depend upon how closely the magnetic centers are made to coincide when the coils are assembled and the tendency for the coils to move if there is a failure to make the centers coincide exactly is present in any type of transformer.

The mechanical forces depend upon ampere-turns and a great deal can be accomplished in reducing them by proportioning the ampere turns per group properly. If the grouping of the coils is done carefully the forces can be kept within bounds and unbalancing among the groups can be minimized by locating taps carefully. If all of these things were not given careful attention, it would be an easy matter to produce a design in which the mechanical forces would exceed the bending and crush-

ing limits of the materials used. The diagrams in the paper show that the coil grouping in the Queenston transformers was carefully worked out and attention was paid to the arrangement of the taps to keep the forces to a minimum under the worst conditions.

The authors have shown in quite a simple way that the forces affecting the coils are practically independent of the shape of the coils because those components which tend to distort them are first of all negligible compared with those which tend to separate the coils from each other, and second they practically neutralize each other leaving effective only those forces which tend to make the coils move as a whole. These forces can be calculated and it is a comparatively easy matter after designing for minimum stresses to apply the bracing necessary to take care of the forces. A section of the paper describes how this bracing is applied.

We are told that the ultimate capacity of the Queenston Station is to be between 600,000 and 700,000 kv-a. This stimulates the imagination to think of the tremendous things that might happen in time of trouble. Even with one generator and one bank of transformers connected and used as a unit, the short-circuit kv-a. capacity could be over a quarter of a million kv-a. and it speaks well for the art that transformers can be designed and built without any misgivings as to their standing up successfully under the worst short-circuit conditions that can possibly occur.

B. A. Behrend: So far as I am aware, there are no cases on record where machines designed with steel plate rotors have gone to pieces. However, there are numerous cases on record, where steel forgings and steel castings have been wrecked, and it is evident that it is the paramount duty of the designer to eliminate the elements of chance in the design and construction of these large units. The element of chance is greatest, where steel forgings are used, next greatest, where steel castings are used, and the least, where rotors are built up of steel plates. There is no question about the fact that it is possible to construct electric generators with either steel forgings or steel castings, but the fact cannot be denied, that the unknown quantity is greater in this case than it is when dealing with moderately thick plates, the structure of which is thoroughly known, which can contain no blow holes, no piping, no shrinkage stresses, and in which the material is subjected to stress in the direction in which its ductility is a maximum.

R. A. McCarty: From the papers presented and the subsequent discussion, it seems to me to be rather generally recognized among designing engineers that there is a proper field in generator construction for the use of both the built up and the cast steel types of rotor designs. As one speaker pointed out, many satisfactory machines have been built with both constructions. It, therefore, appears that the only important matter on which there is any serious disagreement, relates to the exact location of the dividing line which separates the two classes of machines in which the use of the different types of rotor should be employed. Since, as in all engineering work, the application of either design will vary, depending on the experience of the particular group of engineers concerned, it is not to be expected to find the various manufacturers following a common practise, there being no common experience. While we would not presume to take the position that our machine classification which fixes the type of rotor construction is the only correct one, I do want to emphasize the fact that in following that classification our record, contains no single case of which I am aware, of any machine of either construction going to pieces.

B. L. Barnes: I think that we are greatly indebted to Mr. Behrend for giving us the very interesting review of his experience as a pioneer in the design of large high-speed rotor construction. I think that it is generally accepted that the plate construction whether in thin laminations or boiler plate is preferable to the forged steel construction for large machines, but there is also a legitimate field for the employment of the cast steel construction.

As pointed out by Messrs. McCormick, Foster and Williamson each type of construction must be treated according to its own peculiarities, and while a given type is applicable in some machines, yet due to difficulties in manufacture it is not suitable for other machines. For instance in the case of a large generator the laminated rim construction involves the manufacture of very large sheet segments which are ordinarily made by only one or two punch press operations, limited in number in order to realize the economy peculiar to this type of construction. This involves some very nice problems in the designs of the punch and die and the punch press to handle sheets of sufficient thickness to insure ample stiffness, especially in the pole dovetail parts, and it is quite conceivable that in order to use segments of sufficient thickness the number of operations would be increased to such an extent that the economy of cheaper material is more than offset by the increased labor cost. In addition to the advantage mentioned by Mr. Williamson of being able to make overspeed tests on large rotors at the factory the cast steel construction also permits giving each part a careful balance to insure a good running balance of the completed rotor. Nor is there the danger of the balance being disturbed after a long period of operation which might result from the gradual shifting of the punchings to take a permanent seat on the through bolts and dowels.

In reference to Mr. Newberry's comparison of the two types of construction as regards the fly-wheel effect, I wish to explain that definite restrictions were placed on us by our customer as regards the diameter of the stator frame, and if we had been permitted to increase the diameter a few inches the desired fly-wheel effect could have been obtained without the use of the extra wheel sections. As Mr. Newberry has mentioned the laminated rim construction has necessitated more material, due to the radial joints which means a greater radial depth and restriction of the air passages through the rotor. Furthermore the stresses in the laminated rim are not relieved by the arms or spokes as in the case of the cast steel construction with the rim, spokes and hub cast as one piece.

In reference to Mr. Newberry's comparison of cast steel and cast iron upper bearing brackets, it should be noticed that the relatively shallow bracket obtained in cast steel has been taken advantage of for draining the oil pan of the upper guide bearing over the top of the stator windings instead of using a rotating pan on the shaft and draining the oil down through the rotor. Furthermore on the basis of a given deflection a bracket can be designed for cast steel of sufficiently smaller weight than for cast iron to overcome the disadvantage of greater cost per pound, and at the same time obtain a much greater factor of safety. We have experienced as much trouble due to porosity in cast iron construction as in cast steel.

Radio Telephony Range Tests

Nearly 1000 reports have been received by the Bureau of Standards on the signals transmitted from stations KBKA and WLB. A preliminary analysis of 500 reports on transmissions from the former station has been made using a sorting and counting machine very kindly loaned by the Bureau of the Census.

A report has been prepared describing this study entitled "A Preliminary Statistical Study of the Range of Radio Transmitting Stations." Brief attention has been given to the application of the theory of probability to the results of this transmission test. Plans have been made to continue the test through the assistance of the Department of Agriculture, a representative of that department carrying out his work at Minneapolis as a member of the staff of the Bureau of Standards.

Technical Committee Annual Reports, 1921-1922

ELECTRICAL MACHINERY COMMITTEE

To the Board of Directors:

IT has been the aim of the Committee on Electrical Machinery during the past administrative year to extend its usefulness, as heretofore, to a survey of the art through descriptive papers and the arrangement of meetings for their presentation in cooperation with the Meetings and Papers Committee and to assist in the clarification of work in connection with the standardization of temperatures in electrical machinery.

A review of the theory of electrical machinery is opportune from time to time and this Committee has endeavored to follow this idea by inviting a paper on the kinematic reproduction of vector diagrams of induction motors, which was presented by Prof. Karapetoff at the Midwinter Convention. Another paper on "Theoretical Problems in Connection with Induction Motors" was solicited from Mr. B. G. Lamme and was presented at a meeting specially arranged for this purpose at Pittsfield.

The development of large power generating machinery and its application to modern power-house design has been considered in the presentation of important papers on the new development work done at Niagara Falls, on the Canadian side. These papers were presented at the Annual Convention in June, held at Niagara Falls. They describe constructive engineering work of great originality and magnitude.

The problem of the internal heating of coils in alternating current generators, which has been agitated for some considerable time, has received the most careful attention of this committee. At the Pittsfield meeting of the committee held March 16th, the problem itself was fully discussed and it was decided that the designing engineers on the one hand and the operating engineers on the other would present complete experimental data and records at the June Convention. These records were presented by Messrs. Foster, Newbury, and Williamson for the designing engineers, and by Mr. Philip Torchio for the operating engineers.

A most complete discussion of the subject took place, which it is hoped will result in a settlement of this problem by the formulation of rules of standardization, upon which the development work of the art will be based for some time to come.

The efforts of electrical engineers during the past year in connection with the design and construction of electrical machinery have been concentrated very largely upon the subject of greater refinement in the determination of temperatures and upon the development of larger sizes of individual units. This applies particularly to the generators connected to steam turbines and to large water-wheels. The work in the development of the latter, which was so well described by Mr. William M. White in his paper on "Hydraulic Turbine Development" delivered under the auspices of this committee at the June Convention last year, has led to the construction of large hydraulic units at speeds formerly undreamt of. This, of course, was immediately utilized by the electrical engineers for the construction of electric generating units, so that now individual units of capacities of 50,000 kw. are not only being contemplated but actually designed and executed, both for steam turbine connection and water-wheel connection. It is, of course, evident that the latter are very much larger in size on account of their reduced speed.

There is another field in which there is promised great activity and reference is made to the possibilities in the railroad field. It is evident that the condition of the railroads of the country is today such that, unless their present capacity is greatly increased, the railroad system will be unable to do justice to the future of industrial development. It is evident that, through the applications of electrification, the capacity of the terminals, both as regards passenger handling and freight handling, can be enormously increased. This has been shown convincingly in the electrification of the terminels of New York City and Philadelphia, and the sooner the railroads realize the necessity of such work the better it will be for them and for the country at large. Such economic development will naturally carry with it a tremendous stimulus to the entire electrical industry, with the result that the electrical machinery which comes under the scope of this Committee will meet with an area of revival.

The chairman wishes to thank the members of this committee for their active and loyal service rendered failthfully throughout the year.

B. A. BEHREND, *Chairman*

PROTECTIVE DEVICES COMMITTEE

Subcommittee Circuit Breakers and Switches—B. C. JAMIESON, *Chairman*

To the Board of Directors:

Several papers covering certain features of this subject have been presented before the Institute this year, which we feel will be instrumental in improving this type of equipment. The representatives of the Power Club, N. E. L. A. Electric Apparatus Committee, and your committee have cooperated in attempting to clarify interrupting capacity ratings of oil circuit breakers. The three important features in this rating are:

1. The point at which the duty cycle terminates.
2. The condition of the breaker at the end of the duty cycle.
3. The starting point of the duty cycle, whether open or closed position of the breaker.

These points threw this whole matter back to a stage which required discussion of fundamentals supposed to have been thoroughly understood and agreed upon

previous to the publishing of the Hewlett-Burnham-Mahoney paper.

A fairly definite understanding has been reached on the first two points, *viz.*

1. Duty cycle terminates with the breaker in the open position.

2. The breaker is to be capable of closing and carrying full rated current.

There has been so much misunderstanding and difference of opinion regarding the third point, that it was decided to submit the subject for general discussion at the A. I. E. E. Annual Convention at the time of the presentation of the papers on circuit breakers. However, when these papers were presented, much disappointment was felt by operating engineers because of the small amount of desirable data that they contained. On this account the discussions were not very fruitful and the matter of duty cycle remained in practically the same undefined state as before. The opinion of your committee, however, is that the duty cycle should begin with the breaker in the open position, and the duty cycle consisting of closing the breaker on a short-circuit and the breaker interrupting this current. The multiple shot rating to be made up on the basis of repeating this cycle the desired number of times.

The committee also favored the suggestion of the manufacturers that the old standard so-called two shot rating be retained as a published or reference standard for the normal measure of breaker capacity.

Until the committee can get further assurance that its findings would receive more approval, it hesitates to submit these findings as a final report. The committee, however, hopes that the ultimate disposition of the matter will be on the basis as recommended since the N. E. L. A. findings are based on a reluctance to disturb existing manufacturing standards. If this is their principal objection it would appear that there is good ground for believing that, with this removed, they would favor the same definition of duty cycle as we propose. Certainly, it would make for a safer and more logical standard of protection to have a breaker which is capable of closing in on a short circuit at its first operation and particularly is this so in view of the fact that in all subsequent operations it must be able to do so.

In view of the lack of agreement among the various organizations interested in this matter of duty cycle, it is proposed that during the coming year your subcommittee shall immediately begin work on a comprehensive plan for the guidance of member companies contemplating oil circuit breaker tests, specifying the data which are necessary to certify or amplify the correctness of the present definition of interrupting capacity of oil circuit breakers. It is believed that such a course will eliminate to a large extent duplication in tests and will also serve to remove elements of doubt as to the efficacy of the tests, either of which would of course result in furthering the development and reducing the hazards incident to the test. It will serve also to accomplish a more thorough diffusion of results among the interested companies and unify the manufacturers in the line of development and progress.

This program would perhaps be a little more logical if it had been possible to dispose of the duty cycle matter during this last year. However, it is believed that the subcommittee will be warranted in going ahead anyway with a more intensive scrutiny of the fundamentals which were assumed as correct in order to get a satisfactory working definition of duty cycle.

Subcommittee on Grounding

E. C. Stone, *Chairman*

The subcommittee on Grounding of Systems of the Protective Devices Committee was created at the meeting of the General Committee held in New York on Friday, Oct. 14, 1921. The scope of the Committee was defined as follows:

"It was decided that a subcommittee should be appointed to study the methods of grounding and collect such information as it thinks desirable regarding the amount of neutral resistance and special application of relays to grounded systems. This subcommittee was to cooperate with the subcommittee on Relays in properly stating the latter phase of this problem."

Under date of November 22, 1921, the subcommittee was further instructed by the Chairman of the General Committee to make a study of the Protective Devices which would be considered necessary in connection with the use of 66,000 volt underground cables for bringing transmission lines of such voltage into the sub-stations.

It was decided that the best method of approach to this study would be a questionnaire. Accordingly, the questionnaire, of which a copy is attached herewith, was prepared. The essential points which the questionnaire was designed to cover are as follows:

General practise with reference to operation.
Grounded or ungrounded.
Number of points grounded.
Method of grounding.
Operating experience.
Switching practise.
Types of grounding resistances.
Inductive inter-action with signal circuits.
Relay systems.
Protective devices other than grounding used to take care of surges.

On account of the unpopularity of questionnaires, it was decided that this one should be sent out only by members of the committee to their personal friends in the various operating companies. The results, however, have been very gratifying and indicate that the men on this subcommittee are in close touch with

practically all of the important operating companies in the United States.

It was found that the Electrical Apparatus Committee of the National Electric Light Association was making a study of methods and practise in grounding the neutrals of large generating stations. This study was under the direction of Mr. H. C. Albrecht, who has very kindly cooperated with this subcommittee in every way possible and has made available all of the information which he had collected bearing on the subject.

In collecting the data two major sub-divisions have been made, as follows:

(a) Practise in systems which transmit substantially all of their power at generator voltage.

(b) Practise in systems which step up substantially all of their power to transmission voltages above generator voltage.

In order that this committee might work in close cooperation with the N. E. L. A. committee, Mr. P. H. Chase of Philadelphia was appointed to gather the data and prepare the report on Section A. The report on Section B will be prepared by the chairman of the subcommittee.

Up to the present time, 31 companies have submitted complete answers to the questionnaire sent out. These companies represent a total kv., of 5,002,500 and operate 15,804 miles of transmission lines at voltages from 11,000 up 150,000. Thirteen other companies have submitted the essential facts regarding their grounding practise.

Very wide divergence in practise is indicated. Some systems including many miles of line at very high voltages are apparently operating successfully ungrounded, although the trend is strongly towards a dead grounded neutral for systems operating at 66,000 volts or above. For systems operated at lower voltages, resistances of widely varying ohmic magnitude are used. Practise with reference to switching, type of ground used, and other protective devices is also very divergent and some very unique schemes have come to the committee's notice.

As the collection of data is not yet completed, the report of the subcommittee at this time must be merely a progress report. Because of the wide divergence of present practise, the chairman of your committee feels that the subject is of sufficient interest to warrant holding one or two sessions of one of the main quarterly meetings of the Institute. The data should all be in in time to be presented at any meeting after January 1, 1923. In addition to the report on the data collected on practical operation by the subcommittee, it is also recommended that one or two papers be prepared on the theoretical aspects of the subject. The industry is sadly lacking in definite information as to why transmission systems are grounded or not grounded and what factors determine the method of grounding.

Subcommittee on Lightning Arresters

F. L. Hunt, *Chairman*

The publication of the operating data showing the performance of several types of arresters in a paper by Mr. Roper before the Institute in November, 1919, has apparently acted as a great stimulus to the designers and manufacturers of lightning arresters, as at the present time three new types of arresters are being offered for service tests and there will apparently be at least two additional types offered within another year. In addition the two papers on the subject of Lightning Arrester Protection which were presented at the Midwinter Convention have created considerable interest.

The development of equipment for testing lightning arresters with large capacity, current and steep wave front has been of great help in classifying the different types of arresters as to the relative protective value against surges.

The tests made by this method and the analytical studies of the engineers of the manufacturing companies appear to confirm the prediction from the published data previously mentioned, namely, that a lightning arrester to be most efficient as a protective device, should have a minimum impedance to flow of surge current so as to permit a very high current to flow at the instant of lightning discharge.

These tests also indicate that it is apparently entirely possible to devise an arrester which will have a maximum potential across its terminals that will be less than the primary bushings and the primary windings of line transformers as now constructed for distribution voltages will withstand. It is confidently expected that arresters meeting this requirement will be produced by one or more manufacturers and available for general use within the next few years. When this result is achieved, then disturbances from lightning will be practically eliminated from our low potential distribution circuits, except in the few cases of defective bushings, insulation damaged by severe overloading, or direct lightning strokes. The total difficulties per annum in a large system from these causes should not exceed one tenth of one per cent of the total number of transformers installed.

With the case of the lightning arresters for transmission voltages, the situation is somewhat different. There appears to have been no radical improvement in such arresters during the last few years, but with the development of the new types of arresters for the distribution voltages and with the recent improvements in the methods of testing lightning arresters, and with the large amount of attention being given by the engineers of the manufacturing companies to the analytical study of the subject of lightning and lightning arresters, it seems quite probable that the serious improvement in lightning arresters for distribution voltages now in progress will be followed very quickly by corresponding improvements in lightning arresters for the higher voltages.

A paper read at the Midwinter Convention brought out what the prevailing practise is in the use of lightning arresters on circuits of 10,000 volts and over, and also brought out the fact that some prominent engineers differ widely in their views about the use of arresters from the majority of opinions.

A paper by Mr. Creighton pointed out the operating characteristics of the arresters in use today and their application to the conditions that have to be taken care of on transmission lines, and made clear the fact that apparatus now being supplied under the name of lightning arresters has characteristics so widely different that a need has arisen for a classification of lightning arresters, so-called, as supplied to the operators.

The subcommittee is now working on a classification of lightning arresters which will make possible a more complete comparison of the types available and give operating engineers a better basis for choosing the arresters to be used on their lines. We believe such a classification should include the following sub-divisions:

1. Path of initial discharge.
   - (a) No gap in series.
   - (b) No resistance in series.
   - (c) Gap in series.
   - (d) Resistance in series.
2. Rate of discharge at over voltage, normal frequency.
   - (a) High rate (specify limits).
   - (b) Intermediate rate (specify limits)
   - (c) Low rate (specify limits)
3. Rate of discharge at over voltage, high frequency
   - (a) High rate (specify limits)
   - (b) Intermediate rate (specify limits)
   - (c) Low rate (specify limits)
4. Flashover potential at normal frequency.
   - (a) 20 per cent (this will include the counter e. m. f. type of arresters)
   - (b) Between 20 per cent above normal potential and 1.5 times normal potential plus 5000 volts. (This will include the types of arresters consisting of a number of spark gaps with a resistance in series.)
   - (c) More than 1.5 times normal potential plus 5000 volts. (This will include the arresters of the single gap type with resistance in series.)
5. Time required to interrupt dynamic current.
   - (a) No dynamic current follows.
   - (b) Less than 2 cycles.
   - (c) Less than 10 cycles.
   - (d) More than 10 cycles.
6. Attention required in service.
   - (a) None. (This will include arresters like the most recent designs for low distribution voltages, and contained in a sealed porcelain case that does not permit of inspection or adjustment.)
   - (b) Not more than once per season. (This will include some arresters of the wooden box type in which the gaps must be cleaned and perhaps renewed or adjusted.)
   - (c) After every heavy discharge.
   - (d) Once a day or oftener.

Subcommittee on Current Limiting Reactors

N. L. Pollard, *Chairman*

Failures. From information gained by the committee from a number of operating companies that use a considerable number of current limiting reactors, it appears that the manufacturers are gradually overcoming many of the weaknesses inherent in previous designs, so that during the past year there were fewer failures. Several of the failures reported were due to the coil supports being too far apart or the coils not being properly braced. The manufacturers have in most cases remedied these defects and it is hoped that the changes made will entirely eliminate this trouble.

A few failures were evidently caused by the thermal capacity being too small for the service. Both the operating companies and the manufacturers are taking the necessary precautions so as to prevent trouble of this nature in the future.

High Voltage Reactors. One manufacturer reports the new development of a high voltage reactor which is applicable to high voltage tie lines. The windings are constructed and insulated in a manner similar to transformers and are immersed in oil and contained in steel tanks.

In order to get a straight line volt ampere characteristic, the iron cores are omitted and to prevent the flux from passing into the tank and causing excessive losses, a short-circuited winding is placed adjacent to the walls of the tank. In water cooled reactors the copper cooling coils are utilized also for the flux shielding winding.

Outdoor Reactors. One manufacturer reports that one of their first outdoor installations was made in 1916. The performance of these and all others subsequently installed has been satisfactory.

During the past year, another manufacturer has started to build outdoor reactors and it is reported that those that have been installed are operating successfully.

Mechanical Strength of Reactors to Withstand Magnetic Forces. One of the manufacturers of reactors reports exhaustive tests both at large power plants and with a 27,000 kv-a. generator specially built for the purpose of testing electrical apparatus under short-circuit conditions. The tests made with the generator were carried up to the point of destruction of the reactors. These tests clearly demonstrated the short-circuit stresses that the reactors were able to withstand.

Use of Shunting Resistors with Reactors. An exhaustive investigation is being made by one manufacturer of the effect of shunting the reactors with carborundum resistors. It is their opinion that the resistors damp out oscillation and thereby clear the system of disturbances which might build up very high voltages. One large operating company reports the successful operation of about 50 indoor 13,200-volt reactors equipped with resistors.

Losses in Reactors. During the past few years the cost of copper has been low and the cost of electrical energy high. As a result reactors can be economically designed with much lower losses than previously. One of the big advantages is on account of the reactor being able to withstand overloads and short circuits for greater periods of time.

The committee is working on a standard specification for reactors and hopes to have something definite to report before very long.

The committee expects to have three or four papers ready to present at one of the Institute meetings next year. Several of the papers will deal with the design features of reactors from the manufacturer's standpoint and at least one paper will give the experience of an operating company with different types of reactors over a period of eight years.

Subcommittee on Relays

E. A. Hester, *Chairman*

In accordance with the decision reached at the first Protective Devices Committee Meeting of this year, which was held on October 14, 1921, the Relay subcommittee has been actively engaged in the preparation of a paper utilizing the information collected from the replies to a questionnaire sent out by the previous sub-committee. In order to facilitate this work, an editing committee was appointed consisting of two operating and two manufacturing company representatives. On account of the fact that some of the information contained in this questionnaire was at least a year old it was found necessary to get into communication with most of the reporting companies and request up to date data on the various schemes which were reported. Information was also requested on any schemes which might have been installed since the original reply was made.

In addition to the data obtained from the questionnaire, there were also incorporated in the paper sections on the calculation of short-circuit currents, approved practises in relay application and notes on settings and tests. At the suggestion of some of the members of the Protective Devices Committee a section on methods of keeping records of operation were also included.

The question of cooperation with the Apparatus Committee of the National Electric Light Association in the preparation of a Relay Handbook has also been active. Mr. C. H. Sanderson of the New York Edison Company has been appointed Chairman of the N. E. L. A. Relay subcommittee and is to cooperate with the Chairman of the A. I. E. E. Relay subcommittee in this work. The Chairman of the Apparatus Committee and Protective Devices Committee with the Chairmen of the two subcommittees held a meeting in January and decided to prepare a tentative outline of the handbook as the first step in this work. Such an outline has been prepared and submitted to the various interested persons. On account of the work on the paper the A. I. E. E. Relay subcommittee has not had an opportunity of actively engaging in this work but now it is hoped that with the paper completed, the work may proceed more rapidly. It is intended to have the handbook completed some time this fall.

There are several questions which have been docketed for future study by the Relay subcommittee. These are as follows:

1. Protection of high voltage underground cable.
2. Further study of the use and merits of split conductor cable.
3. Apparatus protection. Former studies have been largely on transmission line relays. It is proposed to make a study of protection of generators, transformers, rotary converters, etc., and possibly to present a paper covering the investigation.
4. Special relay applications, such as those used in automatic and remote controlled stations.
5. Further study in standardization. A former subcommittee proposed a standard nomenclature for relays. This has been adopted by the Standards Committee, and there now seems to be a need for some standard form of symbols to represent various relays in single line schematic and detail diagrams. It is proposed to suggest a list of suitable symbols and if approval can be obtained, to use them in the N. E. L. A.—A. I. E. E. handbook.

H. R. Woodrow, *Chairman*

COMMITTEE ON ELECTROCHEMISTRY AND ELECTROMETALLURGY

To the Board of Directors:

This committee has not been active for some years, due principally to the facts that the subjects falling properly within its scope are more advantageously treated on the chemical and metallurgical sides than on the electrical, and have, therefore, been much more actively dealt with by some of the other engineering societies, notably the American Electrochemical Society and the American Institute of Mining and Metallurgical Engineers. At the outset this situation was discussed with the various members of the committee, of whom five showed an active interest in the work.

This discussion brought out in general that the use fulness of this committee lies principally in stating from time to time the status of the art, with particular reference to the power side, as even those members of the Institute who are furnishing electrical equipment

to electrochemical industries do not seem very familiar with the essentials of the processes in which the power is used. It seems desirable at this time to make a general resumé of the various branches of the industry, giving a detailed statement of power requirements, and it is suggested that a symposium be arranged, a page or two being contributed by each of a number of men specializing in the various processes coming under this heading.

A second possibility for work on the part of this committee covers the subject of electrochemical corrosion to underground structures. This is a subject which has been neglected by the sister societies, due probably to the fact that it is a matter chiefly interesting public utility companies and in a sense parallel to inductive disturbances which fall exclusively within the province of the A. I. E. E.

It so happens, however, that there has been a special joint committee for a number of years working on this subject, a preliminary report of which has been recently published in bound form. It seemed to some of us that a public discussion of this report would be advantageous to all concerned, but this was opposed by the chairman of this special committee and at the present writing the President of the Institute has not come to any conclusion as to the desirability of action, although personally he appears to be in favor of it.

Discussion along the general lines of the conversion of chemical into electrical energy appears to belong, in the opinion of most of this committee, within the province of the Electrochemical Society. This, therefore, eliminates the discussion of the various forms of batteries as such, although leaving open their application, as, for instance, the use of storage batteries in power plants.

Altogether the most promising line of work for next year's committee would appear to be the preparation of the general symposium suggested earlier in this report.

Lawrence Addicks, *Chairman*

COMMITTEE ON TRANSMISSION AND DISTRIBUTION

To the Board of Directors:

The Committee on Transmission and Distribution submits its report for the year 1921-1922 under the following headings:

1. Report of the Cable Research Committee.
2. General Review of Construction Problems in Overhead Transmission and Distribution.
3. Underground Distribution Practise on Edison D-C. Systems.
4. Testing of Underground Transmission and Distribution Cables.
5. Foreign Practise in Transmission and Distribution Systems.
6. Review of Papers Submitted During the Year.

As in previous years and in line with the action taken by the Board of Directors a year ago, the report of your Committee summarized under the various headings records the historical progress made in the field covered by the committee, and secondly, indicates the direction in which future progress may be expected.

Your chairman desires to make particular reference to the report of the Cable Research Committee, which has been working jointly with the Underground Systems Committee of the National Electric Light Association.

In the matter of overhead transmission and distribution, as well as several of the other subjects in the report, the work was carried on by subcommittees appointed to investigate each particular topic and to confer with other engineering societies to obtain their views and as far as possible, to outline the tendencies in the entire field of transmission and distribution.

The section of the report dealing with foreign practise is the result of a questionnaire sent by Mr. C. T. Wilkinson, an English member of the Committee, to prominent engineers who are in close touch with European transmission and distribution problems.

Report of the Cable Research Committee

During the past year, one American company has installed some three-conductor cable for operation with a normal working pressure of 33 kv. Other companies are seriously contemplating the installation of single conductor cable for three-phase transmission at 40 kv., 60 kv. and 66 kv. respectively. In the first case, the company is transmitting the energy from a generating station in one of the large cities to their surburban districts. In the other two cases the companies are receiving the current from overhead transmission lines, but on account of the objections to these high voltage lines in the thickly settled portions of moderate sized cities, they are proposing to use underground cable for transmitting the current directly to the distributing substations located in the center of the city. This plan will eliminate the extra step-down transformer substation at the city limits, which would otherwise be necessary. It is also reported that an English manufacturer has taken an order for ten miles of 55,000-volt three-conductor cable for use in Holland and also has completed and has on test a single length of 60,000-volt three-conductor cable.

In connection with these several propositions, it may be well to review our present knowledge and state of the art in this country with a view of determining to what extent the various elements in the design and construction of cables will limit the voltage.

1. Dielectric Losses. On this subject a number of papers has been presented to the Institute in recent years which have included examples showing the reduction in dielectric losses. The leading manufacturers in this country are now prepared to make dielectric loss guarantees on three-conductor cables up to 33 kv. normal working pressure, and on single-conductor cables for somewhat higher pressures. In the cable

having high dielectric loss, the maximum permissible operating temperature is determined by the temperature at which the heating of the cable due to dielectric loss becomes cumulative. For low dielectric loss cables, the limiting temperature is that temperature which will cause permanent deterioration of the impregnated paper insulation.

It is now possible to get lead-covered cable with impregnated paper insulation and with a dielectric loss so low that this feature will not be the determining factor in limiting the voltage.

2. Maximum Permissible Operating Temperature of Impregnated Paper Insulation. The maximum permissible temperature for impregnated paper insulation in lead-covered cables is set forth in the Standards of the Institute as 85 deg. cent., while for similar material in electrical machinery, the limiting temperature is 105 deg. cent. This subject has been discussed in the committees of the Institute for a number of years, and a symposium of papers was presented at the Midwinter Convention in 1921. The views expressed at that time were so widely divergent that the Standards Committee decided that there was no hope of reconciling the conflicting views of the various engineers without additional data. The Research Subcommittee, has, therefore, arranged during the past year for a research investigation on this subject to be conducted by the Massachusetts Institute of Technology under the supervision of the committee. This work has been started and it is expected to continue over a period of about three years. The funds are being contributed by the N. E. L. A. and A. E. I. C.

For single-conductor cables intended for a normal working pressure of 66 kv. between conductors, the pressure to ground would be about 38 kv. and the maximum copper temperature according to the Institute Rules would be 85 deg. minus 38 deg. or 47 deg. cent. While this is about the same as the English practise for armored cables buried directly in the ground, it would be considered rather low in this country for cables to be installed in conduits, and particularly so if there were other loaded cables in the same conduit. Apparently it will be necessary to operate such cables at a very low current density or operate the cables at temperatures materially higher than those permitted by the Institute Rules. A number of the larger American companies however, are now operating their transmission cables as well as their low tension cables at temperatures appreciably above those permitted by the Institute Rules and without signs of depreciation of the insulation. It is suggested that this Institute Rule should be revised upward to correspond with the advances in the art.

3. Maximum Safe Dielectric Stresses. In the past we have apparently confused troubles due primarily to dielectric losses and dielectric stresses. A symposium of papers on this subject was presented at the June Convention. One of these papers indicates quite definitely cable failures due to dielectric stresses are quite rare. In Table I are given data on high voltage cables in this country and in several foreign countries, from which it will be noted that a number of foreign cables are operating at dielectric stresses materially higher than any that are used in this country. This tabulation has been made from data secured from a number of sources; the data regarding the English cables have largely been published in the English technical press and the statements indicated that the 33 kv. cables were being installed for ultimate operation at that pressure, but most of them were being operated

TABLE I

DATA ON HIGH-VOLTAGE CABLES

Location	Date	Normal operating voltage	Size of conductor cm.	Thickness of insulation: Conductor Inches	Thickness of insulation: Belt Inches	Maximum dielectric between conductors kv. per cm.	Stress to sheath
1 Chicago	1921	33,000	350,000	0.297	0.11	29.4	26.7
2 St. Paul	1900	25,000	66,400	0.281	0.125	32.8	27.2
3 Manchester	1921	33,000	382,000	0.25	0.25	32.3	22.8
4 Birmingham	1921	33,000	255,000	0.25	0.25	34.6	24.4
5 English Cable	1921	33,000	95,500	0.25	0.15	41.5	33.6
6 Normandy	1914	33,000	79,000	0.216	0.216	47.3	33.4
7 Paris	1921	60,000	295,000*	0.538	..	..	40.5
8 Erith (England)	1921	33,000	320,000	0.25	0.25	33.6	23.4
9 Rome	1913	30,000	39,500	0.473	†	47.7	
10 Florence	1916	40,000	148,000*	1.18	..	22.3	
11 Turin	1916	38,000	138,000*	0.67	..	28.7	
12 Turin	1917	38,000	99,000*	0.646	..	31.4	
13 Rome	1919	30,000	49,400	0.630	†	38.7	
14 Naples	1919	32,000	237,000	0.590	†	30.6	
15 Rome	1920	30,000	59,000	0.552	†	39.8	
16 Barcelona	1914	50,000	99,000*	0.552	..	45.1	
17 Clyde Valley	..	33,000	237,000	0.512	†	34.4	

Sources of information:

1, 3, 5, 7 Private sources.

2 TRANSACTIONS, A. I. E. E., Vol. XVII, 1900.

4 *London Electrical Review*, April 22, 1921, Page 528.

6 M. Delon at N. E. L. A. Convention 1921, discussion on Underground Systems Report.

8 *Electrical Times* (London), Sept. 29, 1921.

9 to 17 From Mr. Guido Semenza, Milan, Italy.

No. 1 has sector shaped conductors; all others are round.

Dielectric stresses calculated according to Davis & Simon (Journal A. I. E. E., January 1921).

*Single conductor cables. All others are 3 conductor.

†Not given.

at the start at a lower voltage. The best information obtainable however, is that at least one of these cables is now operating 33 kv. The statement is also definitely made that the 33 kv., three-conductor cable in Normandy has been in actual operation since 1914. The single-conductor cable at Barcelona, Spain, has also been in operation at 50 kv. normal working pressure since 1914 without any cable failures except one caused by electrolysis.

In an Institute paper several years ago the statement was made that when the dielectric stress exceeded 20 kv. per centimeter, ionization would occur. Shortly afterward a paper appeared in the technical press giving a list of cables that had been in operation for a number

of years in this country at materially higher stresses. One of them, the 25,000-volt cable on the St. Croix-St. Paul transmission line, is given in the above table.

Engineers are not in accord as to the maximum permissible dielectric stress nor which particular dielectric stress it is that is the limiting feature in high-tension cable design. Some engineers think that it is the maximum stress next to the conductor, but others think that it is the average stress, that is, the total voltage divided by the thickness of insulation. An English engineer contends that the limiting stress is determined by the stress next to the lead and published some data which appeared to support his theory. With such widely divergent opinions, we are apparently not prepared at this time to set the exact limit of dielectric stress that is permissible, but we can be guided however, by the stresses that are found on cables that have been in successful operation for a number of years. Our information along this line should be considerably extended if in the future we are to design high-voltage cables scientifically with the thickness of insulation properly proportioned to the working voltage.

4. Thickness of Insulation. The Standards of the Institute give recommended thicknesses of rubber insulation for various sizes of conductors and working voltages, but they do not include any such recommendations for impregnated paper or varnished cambric insulation. In 1920 the N. E. L. A. Underground Systems Committee included in its report a tabulation of thicknesses of insulation being used by the larger operating companies throughout this country. These thicknesses varied over a rather wide range, and accordingly the committee secured from the American manufacturers their recommendations for the thickness of impregnated paper insulation for various sizes of conductors and working voltages. These recommended thicknesses are shown in Figure 1. In the same figure are also shown the recommendations of the British Engineering Standards Association, several examples of ordinary English practise, the thicknesses being used by one of the larger American operating companies, and also the thickness being used by one of the leading English companies for 20,000-volt cable.

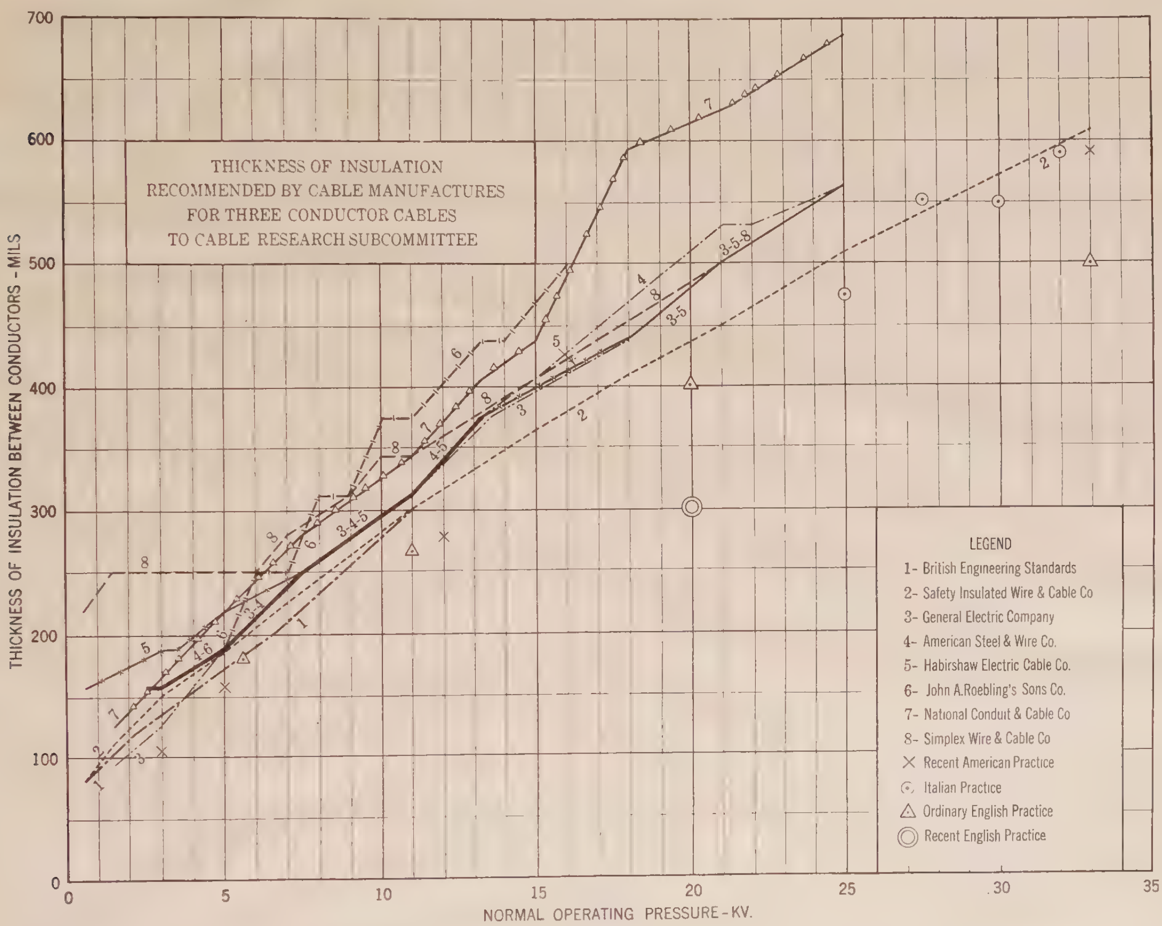

Fig. 1

From this figure it will be noted that ordinary English practise is appreciably below the minimum recommended by any American manufacturer, and also that the recent thickness adopted by one English company for 20,000-volt cable is 25 per cent below their previous practise, and about 30 per cent below ordinary American practise. In Italy the high voltage cables apparently have about the same thicknesses of insulation as are used in this country.

English practise for the installation of underground cables calls for the cables to be made up with steel armor and jute covered and laid directly in the ground. Their conditions for the radiation of heat from the cable are therefore very much better than in the ordinary American practise of cables installed in conduits. According to the best information obtainable the English operating companies carry about the same loads on the various sizes of three-conductor cables as are customary in this country, but because of the improved facilities for radiating the heat, their maximum operating temperature of the copper is about 50 deg. cent. The dielectric losses in their cables are about the same as the best American practise, and at this low temperature, cable failures due to cumulative heating caused by the dielectric losses do not occur. It appears therefore, that when the failures due to dielectric losses are eliminated, that English engineers and operating companies think that they are entirely warranted in reducing the thickness of insulation materially below those that have heretofore been considered necessary.

Two American manufacturers have been operating experimentally, at about double voltage and at room temperature, short lengths of three-conductor cable made from operation at 33 kv. One of these companies reports that after three months continuous operation a case of trouble occurred in one of the cable bells. This trouble was repaired and the cable again placed on test. Cable bell trouble has also been repeatedly experienced in endeavoring to make dielectric strength tests on the same cable, and tests which have been carried up to 212 kv. have been limited by trouble in the cable bell and without causing a failure in the cable. A dielectric strength test of five times normal working pressure is considered by some engineers as a necessary test for their three-conductor cables. If the cable bells are not to be the weak feature of the line, then they should be able to withstand the same test, and if it is impossible to go materially above 200 kv. in a three-conductor cableb ell, then this may place the limit on three-conductor cables at about 40 kv.

5. *Dielectric Strength Test.* The Standards of the Institute mention dielectric strength tests on cables, but cover only the maximum length of the sample to be tested and the limiting temperatures. The rules also specify the test voltage to be applied to full reels of varnished cambric and impregnated paper cables at the factory, but there is nothing in the Rules to give the ratio between the dielectric strength test and the high voltage test applied to full reels. If it is the intention that the Standards of the Institute will prescribe tests which will determine whether or not the cable is satisfactory for the proposed working voltage, then it is submitted that the rules should include a dielectric strength test so as to insure that the cable has a proper factor of assurance.

6. *Impregnation of Paper Insulation.* Some years ago practically all American manufacturers used a vegetable oil base compound for impregnating the paper insulation, and generally these were rosin oil compounds. Cables with paper impregnated with these compounds were entirely satisfactory for the lower working voltages, but in their efforts to reduce the dielectric losses, the leading American manufacturers have gradually changed to a mineral oil base compound. About three years ago the percentage of vegetable compound, as shown by the saponification test, ranged from 0 to 35 per cent, while at the present time the maximum is about 10 per cent.

Practically all manufacturers now use the vacuum process of drying and impregnating, but a number of auxiliary methods are in use by the different manufacturers for the preliminary heating of the insulation for the purpose of removing the moisture. These improved methods of drying and impregnating have served to increase the uniformity of the product as compared with the older open tank methods of impregnation. With the older methods there would occasionally be found a small spot sometimes a few feet long in the center of a length of cable where the paper insulation was entirely devoid of any suspicion of impregnating compound. Such spots of dry paper are not found when the vacuum process of drying and impregnating is used.

Impregnating compounds enter the pores of the paper rather slowly, even under the most favorable conditions. When the cable leaves the factory it generally shows a considerable excess of compound in the interstices of the stranded conductors and between the layers of paper and throughout the fillers. After the cable has been operated at moderate temperatures for a number of years, this excess disappears. Engineers who have investigated such cable and removed the impregnating compound by means of a solvent, report that there is just as much impregnating compound in this impregnated paper that is apparently dry, as there was in the original cable showing the excess compound. It is also alleged that this excess is due to the fact that the paper will absorb only about 90 per cent of the total possible amount of compound during the time that the cable is in the impregnating tanks. It is suggested that with the tendency to higher operating voltages for underground cables it may be found desirable to have some excess compound inside the lead sheath so as to prevent ionization troubles.

One foreign manufacturer is using a thin transformer oil for the impregnating compound and finds that in this way he can get very low dielectric losses. Some American manufacturers have been aware that very low losses could be obtained in this manner but have not pushed the use of this compound as they did not consider that the cable would be entirely satisfactory in other respects. In addition, it is to be noted that the lowest losses reported with the use of this thin transformer oil are not materially below the minimum losses which have been reported by one American manufac-

turer with a mineral base compound. It, therefore, appears that the American manufacturers should continue their recent improvements in methods and materials for the impregnation of high voltage cables, and exhaust the possibilities for reducing the dielectric losses by these means before attempting the use of a very thin impregnating compound.

7. *Depreciation of Impregnated Paper Insulation.* In order to determine the maximum permissible temperature for impregnated paper insulation, when subjected to heat alone, and also when subjected to heat and dielectric stresses in combination, it is necessary to devise some laboratory tests which will serve to measure the depreciation of the insulation. This question, while apparently simple, is in reality a very awkward problem. If the cable is to be allowed to remain indefinitely in the position where first installed, then it might not matter for low voltage cables whether the insulation has become somewhat brittle or charred, but changes in the location of substations or the shifting of business, or changes in the methods of distribution frequently require that cables should be removed and reinstalled in another location. In such an event, it would be necessary for the cable to be bent in order to remove it from the manholes and place it on a reel and again to unreel it for installation in a new location. Apparently, therefore, the cable should be able to pass a bending test without serious injury to the insulation.

A careful comparison of many types of cables does not reveal any single property of the paper insulation which will check with the bending test. Of the various tests such as tensile strength, tearing strength and folding endurance, the latter appears to be the most useful as indicating the toughness of the paper. The tests appear to indicate that if the impregnated paper insulation will stand, say, 1000 double folds in the folding endurance test, then the cable will pass the bending test without difficulty, but if the folding endurance is only a few hundred double folds, then this test gives indefinite results, that is, the cable may or may not pass the bending test. Apparently other factors are involved such as for example, the relation of the width of the paper to the diameter to which it is applied, the tension on the paper, and the amount of lap. The latter variable can be eliminated by applying the strips of paper without lap, and several American manufacturers are now making their high voltage cables in this manner.

This subject of depreciation of the impregnated paper insulation is one of the problems now being investigated by the Massachusetts Institute of Technology as a preliminary step in the studies to determine the maximum permissible operating temperatures with and without dielectric stresses, and the committee would welcome discussion or suggestions from engineers who have had experience along these lines.

8. *Sheath Losses in Single-Conductor Cables.* When single-conductor lead covered cables are used for the transmission of heavy alternating currents, the lead sheath acts as a secondary of a current transformer, of which the primary is the main conductor. In order to prevent high voltages between the lead sheaths of the cables, it will be necessary to bond the lead sheaths at frequent intervals probably in every manhole. The resulting sheath currents may reduce the carrying capacity of the cables by 10 or 15 per cent, the amount of the reduction depending upon the spacing of the cables, the thickness of the insulation and the size of the conductor. The losses in the lead sheaths must also be taken into consideration in calculating the efficiency of the transmission as in amount they may be greater than the dielectric losses. The amount of data heretofore published has been insufficient to make accurate calculations of these losses and it is suggested that such additional data as may be available should be published in the JOURNAL.

GENERAL REVIEW OF CONSTRUCTION PROBLEMS IN OVERHEAD TRANSMISSION AND DISTRIBUTION

The outstanding features of the present status of overhead construction are the continued tendency toward higher voltages, both in transmission and distribution, and the improvements in construction methods as a result of standardization in materials and design.

Supporting Structures. Steel towers continue to be standard practise for extra high voltage transmission lines, especially for the more important trunk circuits. Single circuit flat, single circuit triangular and twin circuit double vertical are the configurations most generally employed, the selection depending on the particular condition to be met. For the very high voltage lines, special designs are required for anchor and transposition towers. The testing to failure of full sized sample towers is often justified in new designs.

Narrow base steel poles continue to be utilized in some sections of the country as substitutes for both steel towers and wood poles. They are especially applicable to high voltage or extra heavy work along city streets.

Special high elastic limit steel has recently been employed in the construction of both towers and narrow base poles with economical results.

Wood poles continue to be used very largely not only for distribution but also for the more moderate voltage transmission lines up to and including 66 kv., and there are in this country a number of excellent examples of wood pole transmission lines at considerably higher voltages. Single wood poles are generally employed for wood pole transmission lines where the voltage is 66 kv. or lower and the spans are under 500 feet; beyond these limits because of the greater clearances and strengths required, it is customary to employ two-pole *A* or *H*-frame construction.

The guying of narrow base steel poles and of wood poles, especially on higher voltage lines, is receiving increased attention, particularly guy insulation, involving as it does a combined mechanical and electrical hazard, has been subject of much careful consideration.

Changes in economic conditions have necessitated changes in wood pole specifications and this year the new tentative specifications of the National Electric Light Association will make their appearance. They differ essentially from the old specifications in providing a larger number of classes from which selections may be made.

With the increased cost of wood poles, butt treatment is receiving the consideration which it deserves. It is now clearly recognized that the open tank treatment is a measure fully warranted economically on the more durable timbers, such as cedar and chestnut; while on those woods which tend to decay above the ground line, a pressure treatment of the entire pole is advisable. Operating companies are realizing that there are no excessive complications involved in the open tank treatment and that the greater length of life fully justifies this treatment in comparison with the relatively inadequate brush treatment.

During the past several years various companies along the southern border have come to realize that much of the pole deterioration which has heretofore been loosely termed "rot", is in fact not a true fungus rot, but is caused by the depredations of insects, particularly termites or white ants. The protection of poles from termites and the saving of poles already attacked offers an interesting field of research in which valuable work may be done.

Insulators. In a general way it can be said that the manufacturers have made good their claims of the past several years that insulators of the latest manufacture are not subject to the rapid depreciation which was the cause of such concern a few years ago. Both in suspension and pin type insulators, perfected methods of design, manufacture and inspection have resulted in a more dependable and substantial product. Research is continuing unabated and we may expect in the not distant future to see even more useful and dependable designs, particularly in the line of high-strength, high-capacity units for extra high-voltage circuits.

The use of static shields to effect the double purpose of equalizing the stress distribution over long strings of suspension insulators and to obviate cascading in case of flashover, is becoming general on extra high-voltage lines.

Various new designs of pins for high-voltage pin type insulators are making their appearance on the market. In particular, the character of thimble is receiving close attention, it being well known that certain types utilized in the past have resulted in high insulator depreciation, and that failures have been incorrectly attributed to insulators which were in reality initiated by the pins.

A standardization of the rating of pin type insulators on a basis of leakage distance, flashover and other physical characteristics, eliminating the nominal voltage rating, appears highly desirable.

Increased attention is being given to insulator selection, as it has become evident to operating companies that in making a selection for any given line, close consideration must be given to climatic and economic conditions. The degree of over-insulation which is advisable or necessary, obviously depends on the relative importance of continuity of service on the particular line in question and the climatic conditions under which it will operate. In particular, the frequency of occurrence of lighting, temperature ranges, both daily and seasonal, humidity, the frequency of cleansing rains and the presence of wind-carried salt spray, dust or the fumes of industrial plants, must be given close consideration. It is only too evident that many of the insulator failures of the past have been due to incorrect selection, to an acceptance of a catalog rating which at best can be only nominal since it ignores the important variables mentioned above.

Engineers who have given the insulator much study believe that the insulator unit for 220 kv. should be larger, so that the number of units may be reduced to about the same number as now used for 100 kv. The following are desirable features for any new insulator design:

1. Length of unit increased to give larger arcover per unit, will use porcelain puncture value to better advantage; and give about 50 per cent more leakage length per given length or string, due to the elimination of one-half the metal connectors.

2. The reduction of the number of units gives much better natural potential distribution and simplifies shield problem.

3. The arrangement of porcelain to metal parts should be such as to reduce air and leakage stresses and eliminate corona.

4. Porcelain surfaces should be arranged to facilitate cleaning by storms and so arranged as to break up the continuity of water streams, which may result from rain, dew or fog.

Conductors. But little change is noted in the line conductor situation. Copper, copper-clad steel, aluminum, steel-cored aluminum and steel continue to be most largely used. For extremely high-voltage lines the nature of the conductor is often determined by limitations of corona.

Increased attention is being given to copper quality. Many companies have found, both for transmission and distribution purposes, that medium hard drawn copper has many of the advantages of hard drawn, without its corresponding disadvantages, and therefore are standardizing on this quality for all overhead purposes.

Close attention is being given to stringing and sagging, various methods using dynamometers or sighting targets, being employed. The attachment of conductors to either pin or suspension type insulators is being given careful consideration. Some form of shim is usually found advisable between conductors and suspension insulator hangers. Full flexibility of suspension strings in all directions at the tower support has

been found desirable, conductor breakage having been noted where the lateral motion was restricted. Sleeves or other mechanical connectors, avoiding the use of solder, long standard on aluminum conductors, are found equally desirable where copper conductors of other than annealed grade are employed.

Miscellaneous Line Hardware. Standardization of line hardware and miscellaneous appliances continues to go forward under the auspices of the National Electric Light Association and much useful work is being done along this line.

Line Sectionalizing and Protective Devices. With increased voltages it is logical that line protective and sectionalizing devices, including fuses, switches and lightning arresters, should receive more careful consideration. Many new and useful devices are constantly appearing on the market, and operating companies now find available a wide selection for any voltage or character of service. Air and oil break switches have improved materially in the last several years. Fuses, particularly for the higher voltages, continue to be a source of difficulty, and some useful research work remains to be done thereon.

Construction Progress. The past year has seen the completion of the highest voltage transmission line to date, this being the 165-kv. line of the Great Western Power Company from Caribou to Valona, California, a distance of 199 miles. Likewise, the year has witnessed the first actual construction of lines to operate ultimately at 220 kv. The Pacific Gas & Electric Company of San Francisco has under construction a 220-kv. line from Pit River Power house No. 1, in Shasta County, to Vaca in the Bay region, a distance of 202 miles.

The Southern California Edison Company has begun the remodeling of its two Big Creek lines, from Big Creek to Eagle Rock, a distance of 241 miles, for 220 kv. operation. These lines are now operating at 150 kv., but the increased power to be transmitted renders the raising of the voltage imperative. It is interesting to note that the Southern California Edison Company has already had in operation, 27 miles of one of the Big Creek lines at 280 kv. and 240 kv. for experimental purposes. This experimental operation was unusually successful, and demonstrated that the addition of a static shield would make feasible, operation at the higher voltage without increased insulation.

Not only do transmission voltages continually show an upward trend, but likewise there is noted a tendency toward increasing the voltage of distribution lines. Increased loads and areas covered have finally made evident the inadequacy of the customary 2300-and 4000-volt circuits for many distribution problems, with the result that 6.6, 11, 13.2 kv. and higher voltages are now entirely standard in many districts for purely distribution purposes. This is a logical outgrowth, first, of the higher voltage agricultural lines, for many years thoroughly standardized in the far west; and second, of the urban substation to substation moderate voltage transmission lines, which it became frequently necessary to tap for larger power customers during the war period. The result has been that companies have become familiar with the economic advantages of true high voltage distribution lines, stepping down directly to the customer's service voltage without the interposition of subsidiary voltages. For such lines automatic induction regulators and other distribution devices are rapidly becoming standardized and in the not distant future we may expect urban and suburban distribution at voltages above 10 kv. to be an ordinary procedure.

The rural line problem continues to be largely an economic one. The types of construction which should be used are well known; the difficulty lies in justifying proper construction for the scattered business involved.

Underground Distribution Practise on Edison D-C. Systems

Low-Tension Feeder Cable. With the relatively steady increase in density of Edison loads, it has been found desirable to increase the size of feeder conductors to as large a figure as may be installed safely, or as the existing ducts will admit.

In all but a few of the largest systems the cables contain no pressure wires. Pressures at the feeder junction boxes are frequently taken over special multi-conductor pressure cables, or in some cases calculated drops are used to estimate what voltage may be delivered at the feeder terminals.

The use of self-contained pressure wires in the feeder cables is quite generally opposed, for the reason that experience has shown that these wires are a very general source of failure; but where the use of this type of cable has persisted it has been found possible to eliminate the possibility of failure due to poor cable design, which was the fundamental cause of dissatisfaction.

A very decided point in favor of the use of feeder cables containing pressure wires has resulted from the adoption of circuit breakers to be installed in the junction box at the feeder termination. These circuit breakers are connected through one of the pressure wires so that they may be tripped either by closing the switch in the substation or as the result of the pressure wire being energized when a fault occurs in the cable itself.

This arrangement gives instant notice of development of serious grounds throughout the length of the cable, and since its general adoption it has practically eliminated serious feeder cable burn-outs.

Edison Mains. The divergence in opinion and practise as to type and sizes of cables to be used for mains seems to be greater than in any other matter. Some companies use rubber insulated cables exclusively, whereas paper insulation is the standard of by far the larger number of companies.

The sizes of mains cable conductors generally range from 200,000 cm. to 2,000,000 cm. In many cases

so-called "sub-feeders" of 1,000,000, 1,500,000 and 2,000,000 cm. are used to interconnect junction boxes without serving as supply for customers directly at all. In other cases the largest mains never exceed 500,000 cm., with the majority of the installation being of only 200,000 cm., and as these small mains are still giving adequate service on some of the largest systems, the question of whether the service given by the larger mains is commensurate with their cost, is very pertinent.

Junction Boxes. The practise as to when junction boxes are to be used is non-uniform to a large degree, and in this particular the tendency seems to be toward a still greater difference. Where Edison tube is used extensively it is agreed that junction boxes must be used frequently so as to provide suitable test points, but where cable in ducts is used the necessity for this is less apparent. Many companies have continued to use junction boxes with cable exactly as had been done with tube, while others have definitely abandoned the use of junction boxes except as feeder terminations,—and excepting always, existing tube. Practise and experience in this case have shown conclusively that there is no greater hazard evident without the junction box than with it for cable main systems.

Fusing Feeders and Mains. There is little or no change being made apparently in regard to whether mains and feeders are to be fused or not. Those companies which have always fused both mains and feeders, fear to change; those that have fused mains only, see no advantage in changing, but feel that they should not fuse the feeders in order to insure more continuous service, and those that have never fused either feeders or mains will not now install fuses, as it is their opinion that fuses would cause a definite lowering of their standard of service maintenance. Some of the engineers feel that it is better to have the fuses blow out than to burn the cable open, while the others feel that service should be maintained as long as possible regardless of overload conditions that may exist during an emergency. No definite agreement on this phase of operation seems to be possible because of the decided difference of opinion concerning the fundamentals involved.

Testing of Underground Transmission and Distribution Cable

As pointed out in the report of last year, this subject can be sub-divided as follows:

1. Testing at factory.
2. Independent laboratory testing by independent laboratories.
3. Acceptance inspection and tests.
4. Testing of installed cable.

1. Testing at Factory. Research work on the part of manufacturers is being carried on although there has been some temporary retrenchment in this direction by some of the manufacturers because of business conditions. On the other hand, certain manufacturers who had not done much research work heretofore are making relatively extensive preparations to do so. The general conditions in this respect are very satisfactory and much progress is promised for the near future,—a condition which could not have been said to be the case, so far as power cables are concerned, a few years ago. All of the progressive manufacturers are not only doing research work looking toward improvements in cable as a whole, but they are exercising more systematic control over the routine manufacturing processes and are giving more systematic attention to minor details, all of which is having its effect in improving cables in a very important respect, namely uniformity. However, no striking developments as a result of any of this research work have been announced during the year.

The practise in regard to the routine factory tests of finished cable has not changed during the year except that dielectric loss testing of occasional whole reels of cable at high temperature is now a regular factory test with several manufacturers.

2. Testing by Independent Laboratories. Research investigations by independent laboratories which have been completed or are now under way are referred to in connection with the report of the work of the Paper Insulated Cable Research Committee.

Independent laboratories are being more and more utilized for:

(a) Making the acceptance inspection and tests of cable being purchased under specifications.

(b) Making check tests of samples of new cable where the purchaser has not made any factory inspection or tests before acceptance and shipment.

(c) Investigating samples from cables which have given trouble in service. The standard tests made in such an investigation of paper insulated cable include composition and physical properties of the paper (tensile strength, folding strength and tearing strength), dielectric loss-temperature characteristic, composition of impregnating compound, ratio of compound and paper in insulation, thermal resistivity of insulation, effect of bending and dielectric strength.

3. Factory Acceptance Inspection and Tests. The specifications for paper insulated cable recently prepared by a joint subcommittee of this committee and the Underground Systems Committee of the N. E. L. A. are not only becoming more generally adopted, but, what is more important, more care is being taken by purchasers to see that the material supplied complies with the specifications. It has always been more or less customary for large purchasers to attach to their orders specifications which were more or less complete but more often than not, that was the only purpose which the specifications served. But there is undoubtedly a trend toward uniform specifications, a simplification which has obvious economic and other advantages.

There have been no innovations in the factory inspection and testing practise. The value of the bending

test has been demonstrated on several occasions. The practise of measuring the resistance of the conductors of each length of cable,—(a practise which has not been universal heretofore) has been found to be well worth while as a check of deficiency in area, excessively short lay and errors in measurement of length. Most of the manufacturers have provided facilities for making dielectric loss tests on whole reels of cable so that now an occasional whole section can be tested as a routine matter.

The routine testing facilities of the manufacturers have, in general, kept pace with the advancement of the art, particularly, for example, in the case of dielectric loss tests, but there is one exception and that is facilities for making puncture tests of samples of cable. Operating voltages have risen to a point where samples of cables designed for such voltages, that is of the order of 33,000 volts and over, cannot always be tested with entirely satisfactory results due to either insufficient voltage being available or, what is more generally the cause, defective methods of preparing the ends and attaching the test leads. With still higher operating voltages being contemplated, this matter becomes more important and it is therefore obvious that the manufacturers have an immediate problem of developing a means of making thoroughly satisfactory tests of this character.

4. Tests of Installed Cable. The use of direct potential rather than alternating potential for high-voltage tests of installed cable is being investigated by operating companies. The large size of the testing equipment which is required for alternating potential tests because of the large charging current, makes it highly desirable to find a satisfactory d-c. method.

For several years one of the larger manufacturing companies has been making direct-current cable testing outfits using a thermionic valve (kenotron) for rectifying purposes. This device is particularly valuable in connection with long high voltage transmission cables. For example, in order to test a 33-kv. transmission cable fourteen miles long at double voltage after installation, as required by the Institute Standards, a transformer of about 2500 kv-a. is required. If a d-c. outfit is used for the purpose, the capacity can be reduced to about 5 or 10 kw. if the outfit is used only for making the high voltage test. However, for reducing the fault after failure so that the trouble can be located, it is necessary to be able to burn the insulation with the high voltage testing set so that the resistance of the fault will be within the reach of the lower voltage testing facilities available, and this may make it necessary to increase the capacity of the d-c. testing outfit to about 50 kw. Even in this latter case, however, the cost is only about one-quarter of the cost of the a-c. testing set.

One of the larger companies has installed one of these direct-current testing sets for use in testing high-voltage lines. While the experience to date does not warrant any definite conclusions it appears reasonable to hope that, with the co-operation of the manufacturers, so as to adapt the device to operating conditions, and with more experience in the use of this testing outfit, it will be possible to entirely eliminate the difficulties that have been encountered and thus render this scheme of testing available for high voltage transmission cables.

In this connection it should be pointed out that all of our experience heretofore has been with the use of alternating direct current for testing purpose and that before the use of direct current for this purpose can be considered successful the proper ratio between d-c. volts and a-c. volts, to secure the same results, should be definitely known. Foreign investigations indicate that this ratio should be about 2.5, but the American manufacturers up to the present writing have not been willing to agree to a ratio higher than 1.5. If the ratio of 2.5 is correct, then a test made with the direct-current voltage limited by a ratio of 1.5 will be entirely without value, as it is not high enough above the normal operating voltage to give results that are at all comparable with those heretofore obtained with alternating current. Two of the cable manufacturing companies have undertaken to make tests of this character and results should be available very shortly. In view of the importance of this ratio, it is recommended that the Standards Committee investigate this subject and incorporate the proper ratio in the Standards of the Institute.

Foreign Practise in Transmission and Distribution Systems

The data on this subject have been submitted by foreign engineers of such prominence that it may be taken as representative of the best and most reliable opinions in their respective countries, namely, England, France, Italy and Norway.

The maximum voltage for transmission systems now in operation in any of the four countries is 110,000 volts. This system which is in Norway is 55 miles in length and has an ultimate capacity of 75,000 kw. In Italy the Pescara system operates at a maximum voltage of 88,000 volts and the maximum length of transmission in bulk is approximately 115 miles. The Energie Electrique du Littoral Mediterranean system is the most important high voltage system in France, and is composed of 560 miles of overhead lines operating at voltages varying from 55,000 to 30,000 volts, and 870 miles of overhead lines operating at voltages varying from 13,000 to 10,000. The total capacity of this system is 111,900 kw. The Societe Hydroelectrique de Lyon system operates at 70,000 volts but is a much smaller system, being composed of 105 miles of overhead lines and having a capacity of only 2984 kw. There is now under construction in France a transmission system to operate at 125,000 volts. The most important English overhead system is that of the North-East Coast Company, the connecting lines of which run from Newcastle up through Northumberland to the southern border of Scotland, and south from

Newcastle through Durham into Yorkshire. This system operates a considerable mileage of overhead transmission line with the great majority of it on wooden poles. The voltage of this system is 30,000 volts. A short transmission line operating at 33,000 volts has recently been put into operation for supplying the City of Chester.

The maximum voltage reported for underground cables in actual operation is 40,000 volts. This is in Italy where underground cable is operated at 40,000 volts on one system, at 30,000 volts on five systems, and at 25,000 volts on six systems. The distribution system for the City of Christiania is composed of 30 miles of underground cable operating at 35,000 volts. In England a 33,000-volt cable has been in operation some time in the Manchester district and a 66,000-volt cable under the River Tee is ready to be put in operation. In France, the Union d' Electricite, a consolidation of a number of small systems around Paris, is at the present time installing a 60,000-volt underground cable system with single-phase cable.

With regard to the comparative reliability of overhead and underground systems, from the point of view of continuity of supply, the opinion in all four countries is that underground cable gives the least trouble. The State Railways of Italy use extensively cables operating at 25,000 to 27,000 volts as primaries for electrification and interruptions due to cable trouble are quite exceptional.

As to the comparative cost of overhead versus underground transmission for approximately the same reliability and continuity of supply, no definite opinions are expressed. In England, up to the present time there has been no great difference between the cost of an overhead line and that of a cable. The reason for this is that the allowances for wind pressure, ice and factors of safety were formerly so stringent that the expense of an overhead line was vastly greater than in the United States. The Electricity Committee of England has, however, brought these regulations up to date and they will soon be issued in pamphlet form. Several lines, based on the new regulations, are at the moment being projected and the estimates show that such lines will be closely comparable in cost with similar lines in America.

In France it is possible to install an overhead transmission line for less cost than a cable. Due to this and also the voltage limiting features of cable, it is the practise of the French engineers to consider only overhead transmission where possible. For Norway and Italy no opinion was expressed as it is thought the question depends very largely on local conditions.

The reports of the most serious troubles encountered in transmission systems differed in each country. In France the chief trouble is that of voltage regulation due mainly to the lines having been overloaded during the war and not having sufficient copper. With this exception the French engineers have experienced no special trouble. In Italy the only element of the line which causes trouble is the insulator and these troubles are not severe. Trouble has been experienced from the breakage of insulators after a number of years of operation. The fracture shows that the break is due to the expansion of the cement, and that the quality of porcelain is not altered by age. Lines in operation from 15 to 25 years are still in good working condition. English engineers have experienced no serious trouble in connection with insulators, towers or poles as the lines in England operate with such a large margin of insulation. Practically no troubles are experienced due to the expansion of cement or to insulator aging. On the other hand, a great deal of trouble has been experienced with insulators by the Norwegian engineers, due to cracking caused by the expansion of cement.

The tendency in all four countries is towards the use of higher voltages. In France the main sources of hydraulic power are over 250 miles from the Paris district, the center of power consumption, and the transferring of this power in large amounts is a problem which must soon be considered. This will necessitate the use of voltages from 165,000 to 200,000 volts. The Norwegian government is now contemplating the use of 150,000 volts on the lines from a new plant now being constructed. The Norwegian engineers are also considering the transmitting of power to Denmark at 220,000 volts three-phase or 200,000 volts d-c. In Italy several overhead 110,000 volt lines are under construction and in England 110,000-volt lines are contemplated.

In England, France and Italy the three-phase system of transmission is the only one considered. Only one direct-current system has been installed in the last ten years. Some Norwegian engineers are of the opinion that while three-phase transmission will take care of any overhead situation likely to be encountered, they are not at all certain that constant current would not be better in many cases on very long lines. They believe that direct-current transmission up to 200,000 volts and 250 amperes is entirely practical and that the insulator question will be greatly simplified.

The tying together of existing hydroelectric or steam plants has been carried out to a large extent in Norway and Italy. Practically all of the large plants in Northern Italy are connected together and similar ties with Middle and Southern Italy are contemplated. In Norway a number of 50,000 to 60,000-volt hydroelectric plants have been connected in the last few years. In France and England a great many of these projects have been contemplated, but few have materialized.

In regard to the arrangement of transformer connections for a system, the opinion of engineers in all four countries is in favor of having the high side connected Y and the low tension side connected Δ.

It has been the experience of the foreign engineers that protection against lightning and power surges on lines up to 60,000 volts is very difficult. In Norway the experience has been that the operation is equally good without lightning arresters as with them. In

both Italy and Norway engineers favor the use of choke coils with resistance and also the use of ground wires. In England the majority of engineers favor the aluminum cell type of arrester. In France the operating companies object to the aluminum cell on account of its high cost and the necessary maintenance. The other types of lightning arresters in use in France do not give satisfaction on large systems.

As regards the use of outdoor substations the engineers of the different countries are divided in their opinions. The English and French engineers favor the use of the outdoor substation and the few in service in these countries have proved satisfactory. In Italy the opinion of the engineers is divided and in Norway no advantage is seen in an outdoor substation for voltages up to 60,000 volts.

The engineers of England, France and Italy have had very little experience with grounding coils, reactance coils or Dressel-Spuhle for limiting electric surges and no opinion was expressed. The Norwegian engineers have had some experience with the Peterson grounding coil and advocate its use on lines up to 66,000 volts.

Review of Papers Submitted During the Year

In the March, 1921, issue of the Journal, Messrs. H. W. Fisher and R. W. Atkinson presented an article on "The Effect of Heat on Paper Insulation."

After discussing in detail the mechanical properties of paper especially as influenced by drying, heating, and impregnating, tests for measuring the changes due to these causes are considered. It is shown that the measurement for tearing resistance is a satisfactory test and two machines for this purpose are described. The results of tests made to determine the effect of heat upon the properties of paper are discussed and measurements of rate of deterioration of paper at different temperatures are given. The relation of these data to allowable operating temperature is considered, and emphasis is placed on the importance of not exceeding intended temperatures through lack of knowledge of conditions.

In the same issue of the Journal is a paper by Mr. D. W. Roper on "Permissible Operating Temperatures of Impregnated Paper Insulation in Which the Dielectric Stress is Low."

This paper deals with the writer's experience with concentric cables which have been operated at high copper temperatures in Chicago. The author cites instances where the insulation of cables known to have been operated at a copper temperature of over 100 deg. cent. steadily throughout the day for a number of months, was found to be in good condition when the cables were removed for reinstallation elsewhere. In one or two cases he has found the copper temperature as calculated by Atkinson's method to be as high as 200 deg. cent. The author believes it desirable to establish two limits of copper temperature; the first to be a lower limit at which the insulation will not be injured even when the temperature is maintained for long periods of time; the second to be an upper limit above which it is known that the insulation will be injured if such temperature is maintained for any considerable time.

A paper on "Transformers for Interconnecting High-Voltage Transmission Lines" is presented by Messrs. J. T. Peters and M. E. Skinner in the Journal for June 1921.

This paper brings out the advantages to be realized by the use of the star-star connection in interconnecting high-voltage transmission lines. This connection however, requires the use of an auxiliary winding in delta to stabilize the neutral point or to decrease the inductance in the ground connection. Consequently the great majority of transformers designed for interconnecting transmission lines are three-winding transformers. Another type of transformer which would be included in this general class is one having an auxiliary winding for feeding a synchronous condenser used in controlling the voltage at the receiver end of the line. The important features peculiar to three-winding transformers when used for interconnecting transmission lines are discussed and the way in which the design and performance of the transformers are influenced by these peculiarities is pointed out.

In the June 1921 issue of the Journal there was an article by Mr. L. L. Elden entitled "Notes on Operation of Large Interconnected Systems."

After describing the interconnections made between the Boston Edison Company's system and the systems of the Eastern Massachusetts Electric Company and the New England Power Company, the author discusses the operation of these connections and the troubles encountered. Some trouble has been experienced on account of short circuits on the systems and to variation in frequencies, but as a whole the operation is considered satisfactory.

Messrs. W. I. Middleton and E. W. Davis presented a paper in the September, 1921, issue of the Journal on "Skin Effect in Large Stranded Conductors at Lower Frequencies."

This paper deals with tests made by the writers to obtain experimental data concerning the effective resistance of large-size stranded conductors to alternating currents of the low frequencies of 25 and 60 cycles. The tests are described and the results tabulated and discussed. The results are also compared with those obtained by using three common formulas for skin effect, in order to determine how far and with what modifications one of the formulas can be applied to stranded conductors. Two of the conclusions drawn are that the skin effect of rope-stranded cables can be calculated to a fair degree of accuracy by assuming the same current penetration as for solid or stranded conductors, and that the current penetration should be calculated from the pitch diameter of the outside layer of strands.

"Use of the Tangent Chart for Solving Transmission Line Problems" is the title of paper presented in the

November, 1921, issue of the JOURNAL by Mr. Raymond S. Brown.

In this paper there is presented a method, devised by the author and based on hyperbolic functions, for solving transmission line electrical problems by means of a special diagram, called a tangent chart. After discussing the general conditions met with in transmission line problems and pointing out the advantages of the tangent chart, the author explains in detail the underlying theory. Diagrams and descriptions are given and the manner of using the chart is explained.

A paper on "Questions of the Economic Value of Overhead Grounded Wires" by Mr. E. E. F. Creighton is included in the January, 1922, issue of the JOURNAL.

After a general discussion of the history of overhead grounded wires and the mechanical vs. electrical factors, the author presents a detailed discussion on the functions of overhead grounded wires, relation of overhead grounded wires to cloud lightning, detrimental effect of grounded wires on semi-insulated structures, relation of grounded wire to direct stroke, overhead grounded wires on wooden pole structures, steel structures and overhead grounded wires. The author analyzes the functions of overhead grounded wires under nine distinct headings. The conclusion reached is that the overhead wire is, in general, a detriment rather than an asset to a semi-insulated or high-resistance pole-line structure. On metal structures no technical function is found detrimental. The relation between the earth resistance and the decrease in protection to insulators is yet to be determined.

The February, 1922, issue of the JOURNAL presents an article on "The Effects of Moisture on the Thermal Conductivity of Soils" by Mr. G. B. Shanklin.

The article describes some thermal conductivity tests made on soils containing different percentages of moisture and compares the results with those of other investigators. These results show that moisture is the predominating factor in determining the thermal conductivity of soils. The relative thermal capacity of various types of perfectly dry soils, such as sand, clay, gravel, etc., covers a range from only one or two, while the addition of moisture increases the range to five times or more that of dry soils.

In the February, 1922, issue of the JOURNAL Mr. E. E. F. Creighton presented a paper "On Deviations From Standard Practise in Lightning Arresters."

This paper is an endeavor to answer questions of practise and the criticism of arresters brought out in an investigation conducted by the Protective Devices Committee. The writer presents a brief review of some of the factors relating to arresters not of the electric valve type and points out the inefficiencies and objectionable characteristics of arresters of low discharge rate. The other extreme, namely, the practise of using no lightning arresters, is then discussed from three viewpoints and the conclusion is drawn that in all three cases the argument in favor of using no lightning arrester is dangerously faulty. A new method of inspection of aluminum arresters is proposed and experiments are given to show that the power factor of cells is a sensitive indication of their condition. The investigation of two arresters in service thirteen years without overhauling is described and the possibility of overhauling arresters in the field is discussed.

A paper on "The Petersen Earth Coil" by Messrs. R. N. Conwell and R. D. Evans was included in the February, 1922, issue of the JOURNAL.

The theory of the earth coils is explained and a discussion is given on the operation of the earth coil under various electrical conditions encountered on transmission systems. Attention is called to the fact that the installation of the earth coil necessitates a change in lightning arrester settings, is unsatisfactory on a transmission network protected by a relay system, and compared to a grounded neutral system will increase the voltage stresses which would be imposed upon line insulators, cable insulation, and switching equipment. Tests were made on a 26,400-volt, three-phase, 60-cycle network of five lines totaling 59.8 miles to obtain information relative to the operation of the Peterson earth coil and to collect data indicating the suitability of such an installation for the suppression of arcing grounds. These tests are described and the results are discussed. The authors have considered five methods of grounding the neutral and give an order of preference for each, from the viewpoint of voltage stresses, current stresses, relay operation, continuity of service and cost. In conclusion the advantages and disadvantages are discussed.

Mr. Herbert Bristol Dwight presented a paper in the March, 1922, issue of the JOURNAL on "Skin Effect and Proximity Effect in Tubular Conductors."

The purpose of this paper is to present sets of curves to determine the effective a-c. resistance of tubular conductors as required to be predetermined by designers for radio installation, for large underground cables with non-magnetic cores, and for electric furnace circuits. The basis of the curves and formulas given in this paper is explained and discussed. Curves are given showing the skin effect for isolated tubes and for stranded conductors. A curve is also shown for proximity effect ratio to be used when the return conductor is near. Typical examples are solved and in conclusion the writer expresses the opinion that it seems scarcely worth while to provide a non-magnetic core with a 2,000,000 cir. mil 25-cycle cable in order to reduce the skin effect, but in other cases considered, the tubular form seems very advantageous.

In the June, 1921, issue of the JOURNAL Mr. F. W. Peek, Jr. presented a paper on "Voltage and Current Harmonics Caused by Corona."

This paper deals with investigation made to study the effects of corona in producing voltage and current harmonics in transmission systems. Tests were made on short three-phase lines of very fine wire so that the

corona loss would be excessive and exaggerate conditions. The different tests are described and the results discussed. Two of the conclusions drawn are that corona will cause voltage and current harmonics, of which the third is the most prominent, and that in properly designed practical transmission lines, the harmonic introduced by corona should be inappreciable.

In the same issue of the JOURNAL was a paper by Mr. Raymond Bailey on "Voltage and Power Factor Control of 66,000-volt Transmission Lines Connecting Two Generating Stations."

The problem which confronted the Philadelphia Electric Company, that of providing for the control of voltage and power factor of the two 66,000-volt transmission lines connecting its Schuylkill and Chester generating stations, is presented in this paper. An outline of the specific problem with its requirements, a discussion of the factors determining the selection of equipment, and a presentation and discussion of data on operating characteristics are included. The situation required that the control of voltage and power of the transmission lines permit of the transfer of energy of either direction, at suitable power factor, up to the rated kv-a. capacity of the lines, with the generating stations operating at approximately equal bus voltages. Other complications are also considered. The comparisons made to determine the most satisfactory type of regulating equipment and the reason for the selection of three-phase induction regulators are given and certain conclusions of more or less fundamental character are brought out.

Messrs. Edwin H. Fritz and George I. Gilchrest present an article on "Modern Production of Suspension Insulators" in the June, 1921, issue of the JOURNAL.

This paper records the progress made during the past few years in the production of electrical porcelain. The information covers the engineering and works organization, the manufacture, and design and test. Each of these topics is discussed in detail and explained. In conclusion the writers state that rapid strides in the manufacture of electrical porcelain have been made in the past few years and perhaps the greatest advancement is in the methods of production in the factory.

In the June, 1921, issue of the JOURNAL there appears a paper by Messrs. E. E. F. Creighton and F. L. Hunt, on "A Solution of the Porcelain Insulator Problem."

After a discussion of the main causes of insulator failures, the writers describe the satisfactory results of a method developed by them for eliminating the cracking of insulators due to the Portland cement. This method consists of thoroughly impregnating the cement, after it has set and thoroughly dried, with a pitch compound. Eleven hundred insulators made in this manner have been in service nearly three years without a failure. In conclusion the authors present comments on the mechanical strength, electrical tests treatment, line testing, aging of porcelain, and open porosity of porcelain.

Mr. W. W. Lewis presented an article in the June, 1921, issue of the JOURNAL entitled "Some Transmission Line Losses."

This paper deals with tests for corona loss made on a 30-cycle, 140,000-volt system and gives a full description of lines on which the tests were made. The tests are described and the results in the form of tabulations and curves are shown. These results are discussed in detail. The conclusions drawn from these tests are presented and it is pointed out that the tests indicate the desirability of operating a transmission line below the corona voltage, thus avoiding corona loss and its accompanying effects.

A paper entitled "Long-Distance Transmission of Electric Energy" by Mr. L. E. Imlay is included in the June, 1921, issue of the JOURNAL.

This paper discusses the long-distance transmission of electric energy from the economic viewpoint, the physical viewpoint and the point of view of service. The economic conditions which justify long distance transmission are pointed out and considered.

In dealing with the plant required for long-distance transmission some of the considerations that effect the design are discussed. A graphic method of determining line performance is illustrated by an example and essential data on other lines are given. Right-of-way, spacing of towers, line insulators, high-tension switches and lightning arresters are discussed.

Service is considered from the viewpoints of what people demand, what perfect service will cost, and the service that may be expected from a large interconnected system consisting of steam plants at the mines, hydro plants, wherever available, and local steam plants.

In the August, 1921, issue of the JOURNAL there is a short article on "Self-Corrosion Not Stray Current Electrolysis, Shown at Selkirk, Manitoba."

This paper describes the investigation of a case of chemical corrosion of iron pipe at Selkirk, Manitoba. The corrosion of the pipe was found to be due to the chemical activity of the solution of so-called alkaline salts in the soil.

Mr. F. G. Baum presented an article on "Voltage Regulation and Insulation for Large Power, Long Distance Transmission System" in the August, 1921, issue of the JOURNAL.

In this paper a standard frequency of 60 cycles is advocated for the national system, and 220,000 volts is proposed as standard for extra large-power, long distance transmission. The voltage regulation of transmission lines is discussed and a simple diagram is given which shows that for a 60-cycle, 220,000-volt line, the line charging current supplies about two thirds of the capacity current required for about 0.8 load or 320 ampere load current, and that for larger loads the synchronous condensers supply leading, and for smaller loads, lagging current. A system of regulation is pro-

posed which will result in practically constant voltage at all points of the line at all loads. The advantages of such a system are given and discussed.

The problems of line insulation are discussed and especial attention is called to the necessity for low air and leakage resistance stresses and results of a large number of tests are given. A new diagram resulting from the analysis of experimental data is given. From this diagram the characteristics of long strings of insulator strings may be calculated, knowing the constants of the unit relatively. Illustrations are presented showing that wet and dry arc-over may be controlled but it is believed best to strive for the elimination of arcs. In conclusion the writer states that while present insulators with some form of shielding or grading will no doubt give more satisfactory results for a 220,000-volt system, such as he advocates, than is now obtained on lower voltage lines, it is desirable that further work be done with a view to developing the best way of handling line insulation.

E. B. Meyer, *Chairman*

(To be continued)

CORRESPONDENCE

THE EFFECTS OF MOISTURE ON THE THERMAL CONDUCTIVITY OF SOILS

To the Editor:

In the interesting paper by G. B. Shanklin appearing in the A. I. E. E. Journal for February 1922, pp. 82-98, which was read and discussed at a time when I was absent abroad, criticisms are made of certain thermal conductivities of moist soils, measured in 1906, and published in the A. I. E. E. paper by Kennelly and Shepard, of June 1907. In those tests, which were made with relatively small buried bare conductors (diameter 3 mm. and less), the thermal conductivity of certain sandy soils, to which known quantities of water have been added, was found to be not much greater than that of the same soils in a nearly dry condition. This relatively small increase in conductivity with moisture was noted with surprise by us at the time; but was not specially investigated, as the effects of moisture on the thermal conductivity of soils was not then a main subject of inquiry. In the series of tests described in the Shanklin paper, however, this question is the main subject of inquiry, and using apparatus specially designed for representing the conditions applying to actual buried cables, (larger diameters, larger contact areas with the soil and with less heat flow per unit of contact surface) results are obtained indicating considerably increased thermal conductivities with increase of moisture in the soil, a very fortunate condition from the standpoint of the operating engineer, if he can keep his cables surrounded by perpetually moistened earth. It should be pointed out, however, that the previous results obtained in the Kennelly-Shepard paper are also of interest and value to the engineer; because they indicate that in cases where the cables are small, and the escape of heat from them is sufficient to dry out the soil on their surfaces and in their immediate vicinity, it may be unsafe to depend upon the increased thermal conductivity of wet soil, and the cables may be raised considerably in temperature. In other words, it is only when the cables are kept in good external contact with soil in which the wetness is steadily maintained, that the advantages of increased thermal conductivity in the water around the cable can be relied upon to carry off the heat.

The Shanklin paper is valuable, not only for the greatly increased data it provides on the thermal conductivity of wet soil; but also for its extensive appended bibliography on the general subject of heating in cables.

A. E. Kennelly

ILLUMINATION ITEMS

By the Lighting and Illumination Committee

HISTORICAL RECORD OF LIGHTING COST

The diagram shown in Fig. 1 gives a graphical record of the cost of light from the early days of electric lighting up to the present date.

In 1885 the best available lamp was a 16-c. p. carbon lamp consuming about five watts per candle and costing \$1.00. At that early date the cost of current was very high, too, such figures as we have been able to locate indicating an average price of about 20 cents per kilowatt-hour. Under these conditions, the cost of lighting

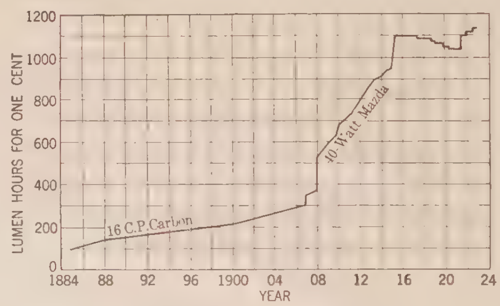

Fig. 1

was so high that the consumer got only 98 lumen-hours for one cent.

Between 1885 and 1906 the developments in lighting which affected the cost of light were as follows:

1. The cost of current decreased from 20 cents to about 11 cents per kw-hr.
2. The price of the 16-c. p. carbon lamp decreased from \$1.00 to 20 cents.
3. The efficiency of the lamp improved from five watts per candle (2.51 lumens per watt) to 3.1 watts per candle (4.05 lumens per watt).

These developments decreased the cost of light to such an extent that in 1906, just prior to the advent of the Gem lamp, it was possible to get 302 lumen-hours for one cent. After the introduction of the 2.5 watts per candle (5.03 lumens per watt) Gem lamp

in 1906, it was possible to get 357 lumen hours for one cent, and further decrease in the cost of current raised this figure to 385 just before the tungsten-filament lamp came into the market.

In 1908 the 40-watt tungsten-filament lamp, giving 32 candle power (1.25 watts per candle), sold for $1.50, and even at this price the new lamp increased the amount of light obtainable for one cent from 385 to 518 lumen-hours. The tantalum lamp, which came out just before the development of the more efficient tungsten-filament lamp, was so quickly superseded by the latter that no data are given on it.

During the period following the introduction of the tungsten-filament lamp in 1908 until the war upset conditions, decreases in costs of lamps and energy and increases in lamp efficiency, all contributed to phenomenal reductions in cost of electric light. By

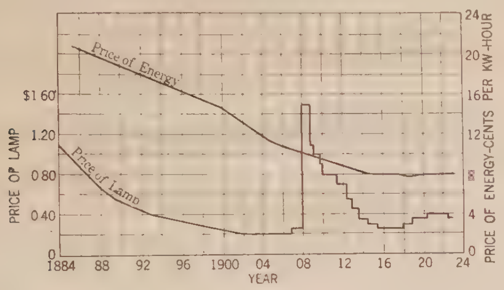

FIG. 2

the end of 1916, with an average current cost of about 8 cents per kw-hr., a price of 27 cents for the 40-watt Mazda lamp, and a lamp efficiency of 9.52 lumens per watt (1.03 watts per hour candle power), the consumer would get 1098 lumen-hours for one cent, or 11.2 times as much as in 1885. At this time the most economical and most efficient lamp, the 1000-watt size, gave 2066 lumen-hours for one cent, or 21 times as much as could be obtained for the same cost in 1885.

From 1918 to 1920 the trend of prices was upward and lamp efficiency downward, so that during 1920, with a 40-watt Mazda lamp, the consumer could get 1045 lumen-hours for one cent.

Now, in 1922, the cost of light is again on the downward trend. Although the average cost of current is still at 1920-1921 levels, some increase in lamp efficiency combined with recent decreases in cost of lamps make it possible for one to obtain at the present time 1138 lumen-hours for one cent, making the cost of light with this size of lamp less than at any other time in the history of incandescent lamps.

THE NECESSITY OF MAINTENANCE IN STREET LIGHTING

If the full effectiveness of a street lighting system is to be secured, it is fundamentally important that a regular and adequate maintenance schedule be adopted. As the following investigation strikingly brings out, it is quite possible for an installation to depreciate to such an extent as to deliver only one-third of the amount of light on the street it would be expected to deliver under good operating practise.

The system on which the following data were obtained is considered to be one of the best designed installations in the country. However, after it had been in operation for approximately one year, to even the casual observer the amount of light emitted by the fixtures was far below that emitted when the system was first turned on. This fact was appreciated by the men in charge, and resulted in an investigation to determine the cause of the apparent decrease in light output.

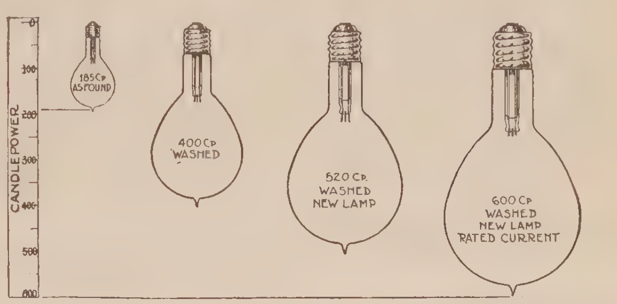

FIG. 1—EQUIVALENT CANDLE POWER OF LAMP, WHICH, IF OPERATED AT RATED CURRENT IN A CLEAN FIXTURE, WOULD DUPLICATE PERFORMANCE OF UNIT TESTED.

The appearance of the units when lighted indicated that the glassware was dirty, and also that the lamps were burning considerably under rated efficiency. In order to determine what percentage of the decrease in candle power should be attributed to the various factors involved, photometric and electrical measurements were made on two representative units. Candle power measurements of the equipment were taken, after being thoroughly cleaned with soap and water. The current through the lamps was checked, and the lumen rating of the old lamps found in the fixtures, determined. The electrical measurements showed that the lamps were burning under rated amperage. An inspection of the lamps indicated that some had burned much longer than their rated life, and the consequent blackened bulbs and sagged filaments gave evidence that they were operating at a very low efficiency.

TABLE I

	Per cent normal candlepower	Per cent increase in light	Equivalent Size of lamp
As found............	31	..	185 c. p.
Unit thoroughly cleaned............	67	116	400 c. p.
New lamp of proper rating............	87	30	520 c. p.
Rated current in new lamp............	100	15	600 c. p.

The accompanying chart (Fig. 1) and the tabulation in Table 1, plotted for one of the units, indicate the weight of the various factors accountable for the decrease in efficiency of the system. Although 600-c. p. lamps were used in this installation the photometric

Panel Display Showing Contrasts

measurements showed that the light output of the fixture as found was only equivalent to the output which would be obtained with a 185-c. p. lamp, operated at rated current in a clean fixture. By washing the lamp and glassware the equivalent lamp size was increased to 400 c. p., an increase of 116 per cent. The substitution of a new lamp of proper rating raised the equivalent lamp size to 520 c. p., an increase of 30 per cent. With the correct current through the lamp the light output was increased still another 15 per cent and was brought up to the rated value, 600 c. p.

The above data call attention forcibly to the necessity of a rigidly-adhered-to maintenance schedule, such as the following, if it is desired to secure an installation which will be satisfactory from the standpoints of both appearance and illumination effectiveness:

1. A systematic and regular cleaning schedule should be in operation.
2. Lamps which have lived far beyond their rated lives and whose filaments have sagged or whose bulbs have become blackened should be removed from the system.
3. The current through the lamps should be maintained at the rated amperage.

PANEL DISPLAY CONTRASTS GOOD AND BAD LIGHTING

A panel display shown in the accompanying illustration has been effectively used to show good and bad lighting practise in the use of decorative wall brackets. This panel attracted considerable attention and comment at the Milwaukee Fixture Market and at the Convention of the National Electric Light Association at Atlantic City.

The first shows a burning tallow candle of our colonial forefathers from which the present wall brackets are copies. Such a method of supporting the candle from the wall was very convenient and, since the candle flame was of low brightness, was very satisfactory.

However, when electricity displaced the candle, electric candle fixtures became common for decorative effect. Very often the lamps were too bright, especially when the wall was dark colored, causing the spot of light to be glaring and annoying. As shown in the third panel this brightness contrast is minimized with a light colored wall though even then the unshaded lamp appears fairly bright. The use of a parchment or diffusing glass shield with light wall coloring provides excellent diffusion of the light for a pleasing and decorative effect.

The fifth panel shows the use of wall brackets for general illumination throughout the room which, though quite common, is harmful practise. The use of large lamps in brackets is certain to be glaring and will prove very disagreeable if the walls are dark colored. The sixth panel shows how general illumination from wall brackets may be obtained by using a reflector large enough to conceal the lamp and of sufficient density to diffuse the light thoroughly.

Wall bracket accessories lend themselves to artistic design and, as shown in the last panel, if of good quality of glassware, pleasing illumination will result.

Fixture manufacturers' clubs have reproduced this display with a view to using it in furthering good lighting practise in the home since the undesirable features of wall brackets are so strikingly contrasted with the decoration and utility that it is possible to secure when properly applied.

LIGHTING DEMONSTRATION CONTAINED IN SUITCASE

A neat, compact outfit for demonstrating what good lighting is, how modern lighting equipment often is abused, and how varied the possibilities of lighting are, is contained in a suitcase no larger than many salesmen's sample case. The complete outfit weighs less than 40 pounds which allows easy handling in a street car, automobile, or passenger train. The suitcase contains 29 sockets and receptacles and 19 switches, more outlets than in the average modern 10-room home.

The story of the development of the incandescent lamp is shown by means of lamps on top of the case. The effect of glare can be shown in a striking manner while interesting demonstrations show the possibilities of shadows and color. A miniature window display shows the application of lighting principles, such as the effect of different intensities, direction or light, color, and spot lighting on the appearance of a show window. An extra background of another color can be slipped in place to show the effect of contrast.

Its great portability will make it possible to give demonstrations on occasions where a larger outfit is impracticable. For talks at luncheons, before small clubs, schools, salesmen's groups and a great many other occasions it will be invaluable in aiding the cause of better lighting.

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A. I. E. E. Meetings 1923

As announced about a year ago, the Board of Directors of the A. I. E. E., at a meeting held in August 1921, adopted the policy of holding four general meetings of the Institute each year, all other meetings to be under the auspices of the various Sections—the intention being that many of the papers submitted to the Institute would be presented at Section meetings; the underlying purpose being to assist in increasing the importance and standards of meetings of the Sections, with the understanding that the papers presented at Sections would be considered for publication in the Institute JOURNAL and TRANSACTIONS, on the same basis as papers presented at general meetings.

In accordance with the above policy there have been four general meetings of the Institute held during the year 1922, namely, the Midwinter Convention, in New York in February; the Spring Convention, in Chicago in April; the Annual Convention, in Niagara Falls, Ontario, in June; and the Pacific Coast Convention, in Vancouver in August.

In accordance with actions taken by the Directors on October 9 and by the Meetings and Papers Committee on October 16, four general meetings of the Institute have been scheduled for the year 1923, as follows: Midwinter Convention, New York, February 14-16; Spring Convention, Pittsburgh in April, Annual Convention, Swampscott, Mass., June 25-29; Pacific Coast Convention, San Francisco, in September.

The Meetings and Papers Committee is already active in preparing technical programs for the above-named meetings. One of the requirements of the by-laws regarding papers is that manuscripts must be received by the Institute not less than sixty days prior to the date of the meeting at which the papers are to be presented; the latest date upon which manuscripts may be received for papers to be presented at the Midwinter Convention is December 10.

A. I. E. E. Developments

At a meeting of the Board of Directors of the Institute held October 9th, a report was presented by a special committee on Headquarters' Personnel, from which the following is quoted:

This Committee was appointed by President Jewett in accordance with the following resolution adopted at the meeting of the Board held at Niagara Falls, June 29, 1922:

> RESOLVED that a committee of three be appointed to report to the Board not later than the meeting of October 1922 on the additions necessary to the administrative organization of the Institute and to make specific recommendations for early action.

Our committee has considered the present activities of the Institute, the trend of development, and the present and probable future demands upon the staff at Institute headquarters.

The large increases in the Institute membership during the past few years have correspondingly increased the scope and extent of the work carried on at headquarters. Many items of work naturally increase almost in direct proportion to the increase in membership, but the additions to the staff have purposely been held at a minimum, due largely to financial conditions. An increasing amount of work is expected of the staff by various committees of the Institute and it appears desirable to provide for reasonable increases for this purpose.

Each year for the past three years, when the budget was under consideration, it has been agreed that as soon as feasible additions should be made to the Secretary's staff, with the object of carrying out more completely certain policies that have been decided upon by the Directors—for example, in connection with the development of the Institute JOURNAL and the encouragement of the activities of Sections. At the meeting of Section delegates during the recent Niagara Falls convention, the desirability of more assistance in formulating the technical programs of Sections was voiced. This, in fact, was in mind when the Board adopted the policy of holding fewer national meetings; the idea being that many of the available papers would then be presented at Section meetings throughout the country, thus increasing the standard of these local monthly meetings.

To carry out these plans, it is, in our opinion, desirable to add to the staff a thoroughly competent man, who can act, for example, as the secretary of the Meetings and Papers Committee and as liaison officer between that committee and the various Sections; thus being in a position to offer good papers to various Sections as opportunity occurs and to arrange with the authors for the presentation of their papers at such meetings, thereby relieving the crowded programs of the limited number of general conventions of the Institute. The duties of this employee would naturally include close cooperation with the Publication Committee, inasmuch as all the papers and discussions presented both at Section and Institute meetings are, in accordance with the policy already adopted, equally available for publication in the JOURNAL. Furthermore, it is generally agreed that the publication of an increasing number of the papers presented at Section meetings will be a large factor in raising the standard of Section meetings.

The report embodied a specific recommendation that a competent man be added to the Secretary's staff to perform the duties outlined above. The Directors voted to approve this recommendation and authorized the Headquarters' Personnel Committee, in conjunction with the Secretary, to employ a suitable man for this work.

The report further recommended that the Secretary be authorized to make further additions to his staff as may be needed during the year, principally in connection with the increasing amount of clerical and stenographic work, and in accordance with the budget of the Finance Committee. This recommendation was also approved by the Directors.

A. I. E. E. Directors' Meeting

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Monday, October 9, 1922.

There were present: President Frank B. Jewett, New York; Past-President William McClellan, New York; Vice-Presidents G. Faccioli, Pittsfield, Mass., W. I. Slichter, New York, N. W. Storer, Pittsburgh; Managers H. M. Hobart, Schenectady, Ernest Lunn, Chicago, L. F. Morehouse, New York, A. G. Pierce, Pittsburgh, Harold B. Smith, Worcester, Mass.; Treasurer George A. Hamilton, Elizabeth, N. J.; Secretary F. L. Hutchinson, New York.

A report of a meeting of the Board of Examiners held October

2 was presented; and the actions taken at that meeting were approved. Upon the recommendation of the Board of Examiners the following action was taken on pending applications: 70 Students were ordered enrolled; 131 applicants were elected to the grade of Associate; 1 applicant was reinstated to the grade of Associate; 9 applicants were elected to the grade of Member; 1 applicant was reinstated to the grade of Member; 1 applicant was elected to the grade of Fellow; 11 applicants were transferred to the grade of Member; 2 applicants were transferred to the grade of Fellow.

Approval by the Finance Committee of monthly bills amounting to $23,641.14 was ratified; and a budget covering the activities of the Institute for the appropriation year beginning October 1, 1922, was adopted as recommended by the Finance Committee.

Upon the recommendation of the Meetings and Papers Committee the Board authorized the following Institute meetings: Midwinter Convention, New York, February 14-16, 1923; Annual Convention, Swampscott, Mass., June 25-29, 1923.

Announcement was made of the reappointment by President Jewett of Mr. C. E. Skinner as a representative of the Institute upon the American Engineering Standards Committee for a term of three years commencing January 1, 1923.

Consideration was given to the Institute's employment activities, now conducted jointly with the national engineering societies of civil, mining and mechanical engineers; and the President was authorized to appoint a committee to confer with similar committees of the other societies for the purpose of reporting recommendations regarding employment activities to the respective governing boards of the societies.

A plan for the organization of an International Engineering Congress to be held in Philadelphia in 1926, as adopted at a preliminary organization meeting held in Philadelphia, July 19, 1922, was presented, calling for the appointment of two representatives of the Institute on a Board of Management of the Congress; and it was voted to accept the plan of organization and to authorize the President to make whatever appointments are necessary in connection therewith.

The President was authorized to appoint representatives on a joint committee to consider the suggested establishment of a National Engineering Museum at the Smithsonian Institution, Washington, D. C., and report to the Board.

A recommendation was presented that each of the Founder Societies appoint representatives on a joint committee to formulate a basis for the establishment of an organization to promote international cooperation of engineering organizations. The invitation to appoint such representatives was accepted and referred to the President with power.

A report was received, and ordered received and filed, from Mr. N. W. Storer, Institute representative at a Conference on Metric System held in Pittsburgh September 6, 1922.

The following Local Honorary Secretaries, whose terms expired July 31, 1922, were reappointed, for the term of two years ending July 31, 1924: Lawrence Birks, New Zealand; A. S. Garfield, France; T. P. Strickland, New South Wales; Harry P. Gibbs, India; John W. Kirkland, South Africa; W. G. T. Goodman, South Australia.

The desirability of making changes in the grades of membership in the Institute was discussed; and it was voted that the President be authorized to appoint a special committee of not more than five members to consider and make recommendations to this Board upon what changes, if any, should be made in the number of grades of membership, the qualifications for these grades, dues, and the methods of transfer from one grade to another.

Reference to other matters discussed may be found in this and future issues of the JOURNAL under suitable headings.

Future Section Meetings

Akron.—November 28, 1922. A film story will be given entitled "The Story of an Electric Meter," with explanation by Mr. R. J. Andrews of the Sangamo Electric Company.

Boston.—November 23, 1922. Subject: "Commercial Aerial Development" "Lighter Than Air," by Edward Schildhauer, "Heavier Than Air," by Prof. Warner.

December 12, 1922. Subject: "Standards—Accomplishment, Trend and Goal." Speaker: Dr. P. G. Agnew. Discussion by Profs. Comfort A. Adams, D. C. Jackson and others.

Detroit-Ann Arbor.—November 10, 1922. Speaker: Mr. A. C. Marshall, Vice-President of the Detroit-Edison Co.

December 8, 1922. Unfilled. Meeting will no doubt be held at Ann Arbor.

New York Section.—On the evening of Friday, November 24, a meeting of the New York Section of the Institute will be held at the Engineering Societies Building, 33 West 39th Street, New York. The papers for the evening by G. A. Pierce, Electrical engineer, William Cramp & Sons, entitled, "The Electrical Engineer on Shipboard" will deal with the problems which have arisen from the necessity of having an experienced electrical engineer on the new motor ships with their electrical auxiliaries. Several of this type of ships have been put out by the Cramp Company and they have been confronted with difficulties, largely due to fixed customs and laws based on the long established use of steam in the marine field. Men prominent in marine affairs have been invited to discuss the paper and from all present indications an extremely lively evening is promised.

Pittsfield.—November 9, 1922. Subject: "Fogs and Clouds." Speaker: Prof. W. J. Humphreys, United States Weather Bureau, Washington, D. C.

November 23, 1922. Subject: "Grinding and Abrasives." Speaker: Mr. Chas. H. Norton, Consulting Engineer, Worcester, Mass.

December 5, 1922. Subject: "In Unknown Baffin Land." Speaker: Mr. Donald B. MacMillan. Illustrated with slides and motion pictures.

Schenectady.—November 3, 1922. Speaker: Mr. W. B. Potter, Engineer, Railway Engineering Dept., General Electric Co.

December 1, 1922. Speaker: Mr. L. T. Robinson, Director of General Engineering Laboratory, General Electric Co.

Toronto.—November 3, 1922. Subject: "Bus Bar Stresses at Right Angle Bends." Speaker: C. H. Van Asperen.

November 10, 1922. Subject: "Electrons." Speaker: Dr. J. C. McLennan.

November 24, 1922. Debate: "Grounded vs. Ungrounded Neutral."

December 8, 1922. Joint Meeting with Illuminating Engineering Society. Speaker: Illuminating Engineer.

Worcester.—November 16, 1922. Subject: "Electric Meters." Speakers: Messrs. C. D. Knight, W. P. I., G. M. Hardy, A. B. Sprague, of the Worcester Electric Light Company.

December 21, 1922. Subject: "Vacuum Tubes." Speaker: Mr. H. H. Newell, Electrical Department, Worcester Polytechnic Institute.

Lehigh Valley Section Meeting

The largest and most successful meeting of the Lehigh Valley Section since its organization early in 1920 was held on October 20th and 21st at Wilkesbarre and Scranton, Pa. A most enjoyable dinner was held at the Elk's Home at 6:30 on Friday evening, October 20th, at which the attendance was 137. A particularly good feature of the dinner being the singing led by a professional song leader.

The dinner which was held in the main ball room of the Elk's Home was followed by a meeting at which the attendance was

149, being members and guests from Wilkes Barre, Scranton, Pittston, Kingston, Hazelton, Allentown, Bethlehem and Easton and a number of other towns located in the territory of the Lehigh Valley Section. At this meeting two most interesting illustrated papers were presented. First—on "Anthracite Mining" by D. C. Ashmead, Mining Engineer, Kingston, Pa., Editor of the *Coal Age*. Second—"Application of Electrical Equipment to Anthracite Mining Work" by Mr. H. M. Warren, Consulting Engineer of the Glen-Alden Coal Company and the D. L. & W. R. R. Co. The first paper traced the history of anthracite mining and showed the gradual improvement and development in mining the coal and handling it. The second paper was also partly historical, but with the main view of tracing the rapid spread of the use of electrical equipment in coal mining work. The illustration of the latter paper included views of the plants to be visited the following day.

On Saturday morning, October 21st, the members and guests assembled in front of the Elk's Home in Wilkes Barre and left by machine for the Sloan Shaft of the Glen-Alden Coal Company where they were taken in an elevator to the first level approximately 500 ft. below ground and visited the Hampton Pumping Plant, which is the largest electrical installation of its kind in the anthracite region. The pumping plant consists of four 12-in. and one 16-in. bronze, centrifugal pump each capable of delivering 4500 cu. ft. of water per minute. The weight of bronze in each pump exceeds 17,000 lb., and the reason for bronze construction is that the mine water contains free sulphuric acid. Power is supplied to the five 1000 h.p., 2300-volt, 60-cycle, three-phase motors through five 300,000 cm. cables suspended in two bore holes from the surface. Water is delivered to the surface at a head of 500 ft. through four 18-in. cast iron wood line pipes.

In addition to the pumps there is also a bucket water lift operated by an 800 h.p. induction motor which is held in reserve. The pump handles all the water from five and a large part of the water from three mines in this district and there is pumped from 8,000,000 gallons of water during the dry season to 25,000,000 gallons during the wet season in each 24 hours. The plant pumps in the course of a year a sufficient amount of water to cover the entire state of New York to the depth of 35 feet.

After viewing the pumping station and water lift, the party then proceeded to the Marvine Breakers of the Hudson Coal Company, which is the newest, completely electrified breaker in the anthracite district. The party here followed the coal from the time it comes up from the mines through the entire process of handling, cleaning, sorting and loading in railroad cars. The construction of the building and the method in which the coal is handled entirely by electrically driven machinery from the time it comes to the surface until it is ready for shipment caused considerable surprise and wonder on the part of the visiting members. They were all impressed particularly with the cleanliness and freedom from dust and dirt of this wonderful example of modern method of handling anthracite coal.

The Glen-Alden Coal Company, has three modern turbine power stations of 60,000 kv-a. capacity, which produce approximately 100,000,000 kw-hr. per year to supply power for the 110,000 h.p. in motors which are installed in the various mines and breakers.

The electric locomotive has practically supplanted the mule for handling the coal below the surface. This company alone has over 300 miles of overhead trolley wire underground, which amount would be greatly increased if wire on the reel type of locomotive which enter the breasts where the coal is mined were added.

After the inspection of the Marvine Breaker, the party proceeded to the Engineers Club of Scranton where a buffet luncheon was served and the meeting officially adjourned. In the afternoon, however, a number of the members and guests visited some of the large power stations in and around Scranton.

American Engineering Council

FUTURE MEETINGS OF THE EXECUTIVE BOARD OF THE AMERICAN ENGINEERING COUNCIL

The next meeting of the American Engineering Council will be held on January 11 and 12, 1923 in Washington, D. C. in accordance with provisions of the constitution. Many vital questions are expected to come up for discussion, which may result in definite instructions being given by the Council to the Executive Board for the ensuing year.

APPOINTMENT OF MINING ENGINEERS ON U. S. COAL COMMISSION

It was decided at the Boston meeting of the F. A. E. S. that at least two of the five members of the proposed Coal Commission be selected from among prominent engineers. As soon as the bill providing for the investigation of the coal situation was passed, J. Parke Channing and Calvert Townley went to Washington to request that these appointments be made.

BOSTON MEETING OF EXECUTIVE BOARD OF AMERICAN ENGINEERING COUNCIL

The regular meeting of the Executive Board of American Engineering Council was held in Boston, Mass., September 8 and 9. Twenty-one members of Council, three alternates and a number of visitors were in attendance. Many important matters were brought before the Board and a decision reached on most of them. The following actions were taken:

Committee vacancies had to be filled and some complete new committees had to be formed in accordance with previous instructions by the Board. The following appointments were confirmed.

To the *Membership and Representative Committee*—Prof. James R. Withrow.

To Draft Bill for the Registration of Engineers—Gardner S. Williams, Chairman; W. B. Powell, James H. Herron.

To the *Foreign Relations Committee*—William McClellan.

To the *Pins and Emblems Committee*—Prof. James R. Withrow, Lloyd B. Smith, Lloyd A. Canfield, A. F. Ganier, B. A. Parks.

Representatives to Engineering Congress at Rio de Janeiro—Thomas T. Read, U. S. Bureau of Mines; F. J. W. Luck, of the F. H. Walker Co.; Calvin W. Rice, V. L. Havens.

The Engineers' and Architects' Club of Louisville, Kentucky, had applied for membership. They were found to be eligible and the Executive Secretary was authorized to submit the application to a letter ballot of the American Engineering Council.

The universal contract form for the building industry, which had been submitted by the Council's special committee, was given formal approval by the Board, after provision had been made to amend it so that wherever the word "architect" appeared there was to be substituted the word "architect or engineer."

The subject of alternates to represent absent members of the Executive Board has been receiving consideration for some time and was finally settled by a vote which approved of alternates and requested constituent societies to send them with the proper credentials whenever the regular member of the Board could not be present. Alternates are to be members of the Amer-

ican Engineering Council, whenever possible. If the regular member is the only member of Council from his constituency, then the alternate need not be a member of American Engineering Council. This decision will become operative as soon as the necessary change in the constitution can be adopted.

The International Engineering Congress, which is to be help in Philadelphia in 1926 is to be participated in by the Federated American Engineering Societies as a result of the formal acceptance of an invitation from those in charge of the Congress. Two representatives will be appointed to the Board of Management.

The proposed articles of incorporation for the Federation were discussed, some amendments suggested and the articles were finally accepted.

Following the idea developed in Mr. Ralston's editorial on "Our Industrial Ideal," the Board authorized the appointment of a committee to formulate a definite plan for presenting the subject to engineering colleges of the country. The theory being that they could visualize to the engineering students the manifest duty of the formulation of the ideals of industrial leadership.

The following rulings of the Committee on Constitution and By-Laws were adopted by the Board:

I. That the clause in Article IV, Section 6 of the Constitution reading "a president to hold office for two years, who shall be ineligible to reelection" does not render ineligible for election as president the incumbent of the office of an unexpired term.

II. That Article IV of the Constitution requires that the elected officers of the Council shall be members of American Engineering Council.

The following reports were received but required no action:

Report of the Executive Secretary.

Report of the Committee on Procedure.

Report of the Treasurer.

Report of the Committee on Publicity and Publications.

Report of the Committee on Classification and Compensation of Engineers.

Report of the Committee on Regional Activities.

Report of the Patents Committee.

Report of the Reforestation Committee.

Report of the Finance Committee.

AFFILIATION WITH ENGINEERING SOCIETIES OUTSIDE OF THE UNITED STATES

The committee which was appointed to make special recommendation on this subject submitted the following suggestions, the principles of which were approved by the Board:

"Associate membership may be extended to national, state and local engineering and allied technical organizations of other countries than the United States.

"Associate Members shall be privileged to send delegates to attend the meetings of the American Engineering Council and to participate in its discussions, but not to vote on questions affecting primarily the United States. They may present to the Council for its consideration questions affecting the engineers in their own or other countries than the United States and may vote upon such questions.

"The expense of delegates from Associate Member organizations shall be borne by the organization or organizations represented.

"Each Associate Member organization shall pay annual dues of fifty dollars and shall be entitled to receive at cost such number of copies of the publications of the Federated American Engineering Societies issued during its term of membership, as it may order prior to publication."

These suggestions were referred to the Committee on Constitution and By-Laws for their approval.

REDISTRICTING AND ASSIGNMENTS OF MEMBERS FOR EXECUTIVE BOARD NEXT YEAR

The Membership and Representation Committee reported that the national societies are now entitled to 44 representatives on the American Engineering Council. If, and when, the Engineers' and Architects' Club of Louisville, is elected to membership, the state and local societies will be entitled to a total of 22 representatives on Council. The proportionate ratio of membership on the Executive Board between the national and local societies will be as 44 is to 22 or as 2 is to 1. There being 24 representatives on the Board, the ratio will be 16 to 8 from the national societies and local societies respectively.

It was therefore decided to give the national societies representation on the Board as follows:

American Institute of Electrical Engineers	5
American Inst. of Mining & Metallurgical Engrs	3
American Society of Mechanical Engineers	5
American Society of Safety Engineers	*3
American Soc. of Agricultural Engrs	
Society of Industrial Engineers	
American Institute of Chemical Engrs	
Total	16

*Three to be distributed among them.

It was further decided by the Board that the districts laid out last year should remain the same with the exception that the states of Illinois, Indiana and Ohio be added to District No. 2, Kentucky be added to District No. 5, Districts No. 1 and No. 2 to be divided so that the New England States will constitute District No. 3. This makes the division of districts for the year 1923 as follows:

District No. 1—State of New York.

District No. 2—Michigan, Minnesota, Wisconsin, Illinois, Indiana and Ohio.

District No. 3—Maine, New Hampshire, Vermont, Massachusetts, Connecticut and Rhode Island.

District No. 4—Maryland, Delaware, New Jersey, Pennsylvania, Virginia and West Virginia.

District No. 5—North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Tennessee and Kentucky.

District No. 6—Iowa, Missouri, Kansas, Nebraska, South Dakota, North Dakota, Wyoming, Colorado and Utah.

District No. 7—Arkansas, Texas, Oklahoma, New Mexico and Arizona.

District No. 8—Montana, Idaho, Washington, Oregon, Nevada and California.

EYE SIGHT CONSERVATION COUNCIL

Election of several engineers and educators to the Board of Councilors of the Eye Sight Conservation Council of America is announced from the headquarters of the Council in New York by Guy A. Henry, general director. Engineers chosen include Prof. Joseph E. Roe, head of the Department of Industrial Engineering in New York University, and Dr. F. C. Caldwell, professor of Electrical Engineering in Ohio State University.

Prof. Roe is a member of the Executive Board of the American Engineering Council of the Federated American Engineering Societies, and president of the Society of Industrial Engineers. Prof. Caldwell is chairman of the Committee on Education of the Illuminating Engineering Society. L. W. Wallace, executive secretary of the Federated American Engineering Societies, is president of the Eye Sight Conservation Council, which plans further to enlist the cooperation of the engineering profession.

Prof. Roe described eye conservation, which is to be intensively carried on in the classrooms and workshops of the nation, as an

important public service made possible largely through the disclosures by the Hoover Committee on the Elimination of Waste in Industry. Enormous losses, Prof. Roe said, were being sustained by the nation through defective eye sight. Surveys in industrial centers and in city and rural schools are showing that economic and physical damage is being caused simply through failure of parents, teachers and factory managers to correct faults which can be remedied.

American Engineering Standards Committee

REVISION OF OVERHEAD LINE RULES

A Sectional Committee has been formed for the revision of Part 2 of the National Electrical Safety Code dealing with the rules for overhead line construction. This committee will conform to the Rules of Procedure of the American Engineering Standards Committee which has adopted the Electrical Safety Code as an American standard. The same committee will draw up standard specifications for crossings of overhead lines with other utilities.

A meeting of the Sectional Committee will be held early in November at the U. S. Bureau of Standards, Washington, D. C. The committee is a large one consisting of about 50 representatives of state utility commissions, utility associations, electrical workers, casualty insurance organizations and other interests concerned with the subject.

CODE FOR ELECTRICITY METERS APPROVED BY A. E. S. C. AS "AMERICAN STANDARD"

The code for electricity meters submitted by the National Electrical Light Association and the Association of Edison Illuminating Companies has received the unanimous approval of the main Committee of the American Engineering Standards Committee as "American Standard."

It is expected that the approval of this code by the A. E. S. C. will bring it into even more general use and will have the effect of greatly reducing the possibility of controversies concerning the installation and performance of electricity meters between meter manufacturers and electric service companies, between service companies and electricity consumers, and between utility commissions and electric service companies.

The Association of Edison Illuminating Companies and the National Electric Light Association have been appointed joint sponsors for the future revision of the code.

A. E. S. C. HANDLING 106 PROJECTS

The growing interest in standardization on the part of almost every American industry is emphasized by the quarterly report of the activities of the American Engineering Standards Committee issued from the headquarters of the Committee at 29 West 39th Street, New York City.

Of the projects which have official status before the A. E. S. C., twenty are concerned with mechanical engineering; seventeen are civil engineering projects; fifteen are electrical; three are automotive; ten are concerned with transportation; ten with ferrous metals; eleven with chemical; five with non-ferrous metals; four with mining; two with textiles; one with shipbuilding and eight projects are of general interest.

Twenty-four standards or safety codes have been approved and thirty-six are up for approval. The remaining forty-six projects represent codes and standards which are either in the process of formulation, or which are now being considered by committees of representatives, designated by the various bodies, industrial, technical and governmental, interested in each particular subject. In this way, more than 200 such bodies are officially participating in the work of the A. E. S. C. through their accredited representatives.

A regular interchange of information as to the status of work under way is maintained by the American Engineering Standards Committee with the national standardizing bodies of Austria, Belgium, Canada, Czecho-Slovakia, France, Germany, Great Britain, Holland, Italy, Japan, Norway, Sweden and Switzerland. This information is issued in the form of quarterly reports and includes a statement of the status of each project on which work is actively under way.

AMERICAN ENGINEERING FOUNDATION

ALFRED D. FLINN APPOINTED DIRECTOR

The newly created office of Director of the Engineering Foundation has as its first incumbent Alfred D. Flinn. This post was necessitated by the expanding activities of the Foundation, which is composed of the Four Founder Societies of civil, mining, mechanical and electrical engineers. Mr. Flinn will retire as Chairman of the Engineering Division of the National Research Council, but will continue as secretary of the United Engineering Society in order that the Foundation may keep in close touch with the Founder Societies.

Mr. Flinn is widely known by engineers as an editor, author of books on engineering, and as a practical engineer, and is identified with the movement to promote world unity, aid research and organize the profession of engineering in this and foreign countries. He is a member of the American Society of Civil Engineers, American Society of Mechanical Engineers, National Research Council, American Water Works Association, New England Water Works Association, Boston Society of Civil Engineers and Harvard Engineering Society.

Institute Prizes

At the meeting of the Board of Directors of the Institute of April 16, 1921, recommendations were approved establishing two Institute prizes to be awarded yearly to authors of worthy papers. The 1921 transmission prize was awarded to F. G. Baum for his paper presented at the Salt Lake City Annual Convention, June 1921. Although all Sections were notified early in the year and announcements were printed in the JOURNAL, no "First Paper Prize" was awarded as no paper was offered in competition. The following extracts from the report of the Committee on Coordination of Institute Activities embody the essential features of the procedure to be followed as outlined by them. Members of the Institute are reminded that January 15, 1923, is the last date for submitting to the Secretary papers that are to be considered in competition for the 1922 awards.

THE FIRST PAPER PRIZE

(1) This prize, established by the Board of Directors of the Institute, January 14, 1921, shall consist of $100 cash, and a suitable certificate, to be awarded each year to the author of the paper which is designated by a duly authorized committee of award as the most worthy original paper presented during the year at a meeting of any Section of the Institute by a member of the Institute who has never before presented a paper before the Institute or any of its Sections.

(2) To be considered for competition, the author, or an officer of the Section at which the author's paper was presented, shall submit the paper to the committee of award, by means of a written communication to the Secretary of the Institute, prior to January 15 of the year following the calendar year in which the paper was presented.

(3) Papers by joint authors are eligible for this competition, provided both authors meet the qualifications, in which case the prize shall be divided equally between the authors.

(4) The award shall be made by a committee consisting of the Chairman of the Meetings and Papers Committee as chairman, and the chairmen of the technical committees of the Institute, prior to June 1.

(5) The prize shall be presented at the Annual Convention of the Institute.

(6) The paper shall be published in the monthly JOURNAL or annual TRANSACTIONS of the Institute, or both.

(7) Manuscripts shall be submitted in duplicate and shall be typewritten on one side of paper of approximately 8½ by 11 inches. The letter entering the paper in the competition need not be accompanied by duplicate copies of the paper, provided suitable manuscript copies in duplicate have been submitted previously.

THE TRANSMISSION PRIZE

(1) This prize, established by the Board of Directors January 14, 1921, shall consist of $100, and a suitable certificate, to be awarded each year to the author of the paper which is designated by a duly authorized committee of award as the most worthy paper dealing with the art of transmitting electrical energy over considerable distances, presented during the year by a member of the Institute, at a meeting of the Institute or of any of its Sections.

(2) To be considered for competition, the author shall submit the paper to the committee of award, by means of a written communication to the Secretary of the Institute, prior to January 15 of the year following the calendar year in which the paper was presented.

Paragraphs three to seven as printed above under the heading "The First Paper Prize," also apply to this award.

Opening Session of the International Engineering Congress

The inaugural session of the International Engineering Congress (See August and September JOURNALS), was held Sunday evening, September 17, in the Club de Engenharia (Engineering Club), the large assembly hall of the Club being filled to capacity. Dr. Pires do Rio, Honorary President of the Congress gave a welcoming address in behalf of the Brazilian government, after which he spoke of the purpose and need of the Engineering Congress and Engineering as a profession.

Mr. Verne Leroy Havens, delegate of the American Society of Civil Engineers and Director of the "Ingineria Internacional," made an address on International Engineering.

Federal Senator Dr. Sampaio Correia in behalf of the Brazilian Congressmen, spoke at length on what engineering had done for Brazil, and also on the advantages of the Engineering Congress. He closed by pointing out that Brazil had everything to gain from the presence at this Congress of illustrious foreign members of the various Engineering Societies, and that she should take every advantage of the opportunity to accomplish as much as she possibly could.

Dr. Sebastiao Sampaio, Brazilian Commercial Attaché at Washington, gave a resumé on the history of the organization of the Congress in the United States for which he is responsible. He stated that in this moment of reconstruction the world needs more than ever an extended international study of the vexed problems of scientific, industrial, and commercial engineering, and the realization of this was the principal reason for the decision to hold an International Engineering Congress in Rio in conjunction with the commemoration of Brazil's 100th anniversary of Independence. Then too, South America being one of the least developed countries in the world, the discussion of the exploration of its mines and the development of its cataracts and other engineering projects was thought of as another reason for holding the Congress here.

Dr. Estanislan A. Zawels spoke in behalf of the Argentine Republic, after which a closing address was made by Dr. Getulio das Neves, the President of the Congress.

The Congress was divided into eight sections the officers of which are as follows:

CENTRAL COMMISSION: President, Dr. A. Getulio das Neves; First Vice President, Dr. Santiago Brian; Second Vice Pres., Dr. Francisco Mardones; First Secretary, Dr. Alvaro C. Niemeyer; Second Secretary, Dr. J. Simao da Costa.

FIRST SECTION: (Overland, maritime, fluvial, and aerial transportation. The Pan-American Railway. Practical means of construction.) President, Dr. Santiago Marin Vicuna; First Secretary, Dr. Calixto Paulo Souza; Second Secretary, Dr. Alvaro dos Reys.

SECOND SECTION: (Iron Metallurgy): President, Col. C. H. Crawford; First Secretary, Dr. Britto Passos; Second Secretary, Dr. Thomas Read.

THIRD SECTION (Fuels): President, Dr. Heitor Escardo; First Secretary, Dr. Prado Lopes; Second Secretary, Dr. Fernando Dias Paes Leme.

FOURTH SECTION (Hydraulic Power.—Its Utilization as Motive Power.) President, A. W. K. Billings; First Secretary, W. Y. Sheldon; Second Secretary, Dr. Getulio Luiz de Nobrega.

FIFTH SECTION (Sanitation, Dams, and Irrigation): President, Dr. Francisco Saturnino de Brito; Secretary, Dr. Antonio Guedes Nogueira; Second Secretary, Geo. Schobinger.

SIXTH SECTION (Maritime and Fluvial Ports): President, Calvin W. Rice; First Secretary, Dr. Alfredo Lisboa; Second Secretary, Dr. Alvaro Lessa.

SEVENTH SECTION (Machinery for Agricultural and Industrial Purposes): President, Dr. Barbosa Gonc Ives, First Secretary, Dr. Charles Anthony; Second Secretary, Dr. A. S. Roberts.

EIGHTH SECTION (Standardizing of statistical methods in ports and railways): President, V. L. Havens; First Secretary, Dr. Eduardo Garcia Zuñiga; Second Secretary, Dr. Gentil Tavares.

National Exposition of Power and Mechanical Engineering

TO BE HELD AT THE GRAND CENTRAL PALACE, NEW YORK

The National Exposition of Power and Mechanical Engineering will be held at the Grand Central Palace, New York City, December 7-13, in cooperation with national societies interested in fuel economy and in production and use of power.

The exposition will open on the closing day of the Annual Meeting of the A. S. M. E., and its program has been arranged so that the members may visit the exhibits. A full list of subjects for discussion has been arranged for this meeting. Professional Divisions on Aeronautics, Ordnance, and Forests Products will hold sessions of general interest to the engineering profession. The American Society of Refrigerating Engineers is to hold its meeting in New York, December 5, and its members will be admitted to the exposition. Various chapters of the National Association of Stationary Engineers are planning to attend, and the New York building Superintendent's Association will attend in a body. The exposition has as an Advisory Committee a group of able and representative men, among whom are Irving E. Moultrop, Dexter S. Kimball, Alexander G. Christie, Calvin W. Rice and others.

PERSONAL MENTION

JOHN S. TIMMONS has been for the past two years in the manufacturing business under his own name in Philadelphia, Pa.

RAYMOND WOOD has become associated with the Western Electric Company, Chicago, where he is Central Office Engineer.

EUSTACE C. SOARES has severed his connection with Ophulus & Hill, New York City, and is now in general practise in Newark, N. J.

G. STANLEY PHELAN has resigned his position with the Lord Electric Co., Boston, Mass., and is now with the E. L. Phillips Co., New York City.

H. C. PRADO has resigned his position as City Engineer of Pereira (Caldas) and has taken up general practise in Santander (Cauca), Colombia, S. A.

C. S. LAUDIS has resigned his position with the Federal Shipbuilding Co., and is now associated with the Pennsylvania Power & Light Co., at Hazelton, Pa.

A. C. SCHLOTH has resigned as Assistant Electrical Engineer for the General Electric Company of Lynn, Mass., and is devoting his time to patent work for himself.

LELAND B. WOOD, formerly Manager of the Municipal Lighting Plant in Taunton, Mass., has been appointed Manager of the Municipal Lighting Plant, Hudson, Mass.

H. C. MILLER has severed his connection with the Utah Power & Light Co., Preston, Idaho, and is associated with the Eastern Oregon Light & Power Co., Baker, Oregon.

Walter A. Boden, until recently connected with the Edison Lamp Works, Newark, N. J., resigned to accept a position with the Niles, Bement, Pond Company, Plainfield, N. J.

Harris Laven, formerly Electrician for D. P. Robinson & Co., Turtle Creek, Pa., is now connected with the Westinghouse Electric & Manufacturing Co., at East Pittsburgh, Pa.

Clarence J. Pagel, formerly employed by the Robbins & Myers Company, Springfield, Ohio, is now connected with the Ohio Electric & Controller Company, Cleveland, Ohio.

George K. Scribner has resigned as Vice-President and Factory Manager of the Boonton Rubber Mfg. Co., to become President of the Boonton Molding Company, Boonton, N. J.

Melvin D. Engle has terminated his affiliation with the Consolidated Gas, Electric Light & Power Co., of Baltimore and is now connected with McClellan & Junkersfeld, New York City.

A. T. Gustad, formerly connected as Electrical Engineer with Murril & Co., New York City, is now connected with the American Gas Accumulator Co., Elizabeth, N. J., as Designing Engineer.

Lynn G. Barnes, formerly with the General Electric Company Schenectady, N. Y. is now Resident Engineer and Electrical Superintendent for the International Paper Company at Franklin, N. H.

Lloyd F. Hunt has severed his connection with the Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., and is now connected with the Southern California Edison Company, Los Angeles, Cal.

A. D. McKerrow has accepted a position with the Westinghouse Electric & Manufacturing Co., in Worcester, Mass., having resigned from the employ of the New England Power Co., Worcester, Mass.

Grayson B. McNair, formerly Professor of Electrical Engineering at Colorado College, Colorado Springs, has become associated with the Westinghouse Electric and Manufacturing Co., at Denver, Colorado.

Allen McR. Harrelson has severed his connection as Vice-President of the Galvin Electric Manufacturing Company of St. Louis, Mo., and is associated with the Dayton Fan and Motor Company of Dayton, O.

P. M. Duncan has severed his connection with the Allis-Chalmers Manufacturing Co., Milwaukee, to accept a position as Method Engineer with the Western Electric Company, Hawthorne plant, Chicago, Ill.

George O. Bason has resigned from the employ of the General Electric Company, New York City, and is now Local Manager of the Poughkeepsie district for the Central Hudson Gas & Electric Company, Poughkeepsie, N. Y.

J. E. Shrader, who has been employed by the Westinghouse Electric and Manufacturing Company for the last six years, has resigned his position to become Head of the Department of Physics at Drexel Institute, Philadelphia, Pa.

Earl R. Witzel resigned his position as Manager and Treasurer of the Groton Electric Company, Groton, S. D. and has become Vice-President of that company and is organizing a two-year electrical course at the University of Wyoming.

M. N. Blakemore, Managing Editor of Moody's Investors Service, has been elected Vice-President of that concern and will have charge of the Sales Organization. Prior to this connection he was economist for the Equitable Trust Company of New York.

J. H. McDonell, who was in charge of electrical construction work for the Capital District Engineering Co., of Albany, N. Y., with headquarters in Utica, is now in charge of transmission distribution and trolley system for the Monogahela Power and Railway Company, Fairmont, W. Va.

Walter H. Harvey, formerly Supervising Inspector of the Winding Dept., Westinghouse Electric & Mfg. Co., Newark, N. J., has joined the Engineering Department of the New York Telephone Company, New Jersey division, as Power Plant Inspector, with headquarters at Newark, N. J.

A. R. Cheney, formerly Electrical Aide, Bureau of Engineering, Navy Department, Washington, D. C., has resigned his position to take up general practise in Washington, in the firm Cheney & Weschler. For eighteen years Mr. Cheney was associated with the Engineering Dept. of the Philadelphia Electric Company, and in 1917 he entered the Navy Department to assist in a consulting capacity in the development of electrical propulsion for battleships. For one year previous to this work he was connected with the Westinghouse Electric and Manufacturing Co., at East Pittsburgh. Mr. Cheney is a Fellow of the American Institute of Electrical Engineers, a member of the American Society of Mechanical Engineers, a member of the National Electric Light Association, a civil member of the American Society of Naval Engineers and a member of the Washington Society of Engineers.

Obituary

George J. Blum of Charlotte, N. C., Associate of the A. I. E. E., was killed in a collision between his automobile and a train at Linwood, N. C. on September 26th.

Frank S. Washburn, late president of the American Cyanamid Company, died after a prolonged illness at his home in Rye, N. Y., on October 11th. Mr. Washburn was an Associate of the A. I. E. E.

William A. La Due, Division Superintendent of the Public Service Electric Company, Jersey City, N. J., died on September 30th. He had been in electrical work in Jersey City for many years, and was elected to Membership in the A. I. E. E. during the current year.

Thomas S. Haddaway, Engineer for the Steam Engineering Department, Union Electric Light & Power Co. of St. Louis, Mo., and Associate of the American Institute of Electrical Engineers, died after a brief illness on September 23rd, at his home in Webster Groves, Mo.

Edward O. Lanphier, who was elected Chairman of the Yale Branch, A. I. E. E., for the coming year, died at the home of his parents, at Springfield, Ill., in September. Mr. Lanphier had an exceptional record as a student, having received a quality credit in every subject in his class during his three years at Yale. He had also been awarded prizes, one the result of a competitive examination in mathematics. These prizes, with additional funds, will constitute a fund for establishing a memorial prize at Yale in the school of electrical engineering.

John Forrest Kelly, electrical inventor and pioneer in electrical research in this country, died at his home in Pittsfield, Mass., October 15th. He was born in Ireland in 1858, but came to the United States when a boy. His technical education was received at Stevens Institute, graduating in 1878 with the degree of B. S., and in 1881 received the degree of Ph. D. His first employment after graduation was in the laboratory of Thomas A. Edison, and afterwards was connected with the Western Electric Company and the United States Electric Lighting Company. In 1892 he organized with William Stanley and C. C. Chesney the Stanley Laboratory Company, Pittsfield, Mass., where his work in polyphase transmission at high voltages won him national recognition. Mr. Kelly received more than ninety United States patent grants for the utilization of electricity, among them a piano player and the Cooke-Kelly food-drying process. He was a Fellow of the A. I. E. E., member of the American Electrochemical Society and of several foreign electrical societies, and the recipient of a number of honorary degrees. He is survived by his wife and two sons.

James M. Petrie, Chief Engineer and General Superintendent of the Virginian Power Company, died suddenly at his home at Charleston, W. Va., on Monday afternoon, October 9, 1922.

Mr. Petrie was born at Jersey City, N. J., on June 18, 1883 and received his education in the public schools at Brooklyn, correspondence courses in this country and England and as an engineering apprentice for the Robert White Engineering Works

of Brooklyn. His early work was confined to marine engineering and for some three years he held the position as Chief Engineer on ships of the American Hawaiin Steamship Co., later being engaged in steam and electrical construction work in Mexico, Inspection work for the Maryland Casualty Co. and as chief engineer for plant and distribution work for Messrs. Kops Bros., New York.

After spending two years in the City of Panama, Panama, as Chief Engineer for the Panama-American Corporation, Mr. Petrie became Chief Engineer for The Virginian Power Co., and subsequently was appointed its General Superintendent in charge of all engineering and construction work, also system operation. He was Vice-President of the Engineering Service Corporation of Charleston, W. Va., and President of the Nitro Power Co., o Nitro, W. Va.

Mr. Petrie is survived by his wife, a son and daughter. He became an Associate of the American Institute of Electrical Engineers in 1918.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

BOOK NOTICES SEPT. 1-30, 1922

Unless otherwise specified, books in this list have been presented by the publisher. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

American Fuels.

By Raymond Foss Bacon and W. A. Hamor. First edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 2 vol., illus., diagrs., 9 x 6 in., cloth. $12.00.

The editors of this volume have attempted to condense into a series of specially prepared chapters the fruits of the experience of specialists, and thus present an authoritative account of all American fuels of technical importance. It is intended to give imformative summaries of sound practise and provide such information as will assist the engineer to decide upon the most suitable fuel to use or the changes to make in using fuel or heat in order to get the highest efficiency in plant operation.

Les Axiomes de la Mecanique.

Par Paul Painlevé. Paris, Gauthier-Villars et Cie, 1922. (Les Maitres de la Pensée Scientifique.) 111 pp., 7 x 5 in., paper.

In this small book Professor Painlevé sets forth, with a minimum of mathematical terminology, the axioms of mechanics, as laid down by the founders of the science. From these he proceeds to a description of the modifications proposed by recent theories. His book is therefore not only a thorough study of the fundamental axioms of the subject but also an introduction to the theory of relativity.

Bearings and Bearing Metals.

First edition. N. Y., Industrial Press; Lond., Machinery Publishing Co., 1921. (Machinery's Dollar Books.) 120 pp., illus., diagrs., 9 x 6 in., paper. $1.00.

A book of practical information upon plain bearings, in which the various types are shown and their suitability for various purposes explained. Information is also given on the composition and properties of bearing metals, the service to which they are adapted and proper methods of lubrication.

Beitrag Zur Berechnung der Dampfturbinen auf Zeichnerischer Grundlage.

Von Erich Henne. Berlin, Julius Springer, 1922. (Forschungsarbeiten auf dem Gebiete des Ingenieurwesens. Heft 260) 58 pp., diagrs., chart, 10 x 7 in., paper. 20 Mk.

Describes a simplified method of determining the dimensions of the stages of a turbine, for any given efficiency, by means of graphic charts. The charts are given in the book, with examples of their use. They are based upon the relation between the indicated efficiency, speed of revolution and the heat drop discovered by Loschge. By use of the charts, the author claims, much wearisome calculations can be avoided without any loss of accuracy.

Coal Trade.

By Sydney A. Hale. Forty-eighth annual edition. N. Y., Estate of F. E. Saward, 1922. 254 pp., 8 x 6 in., cloth. $3.00.

A statistical and economic review of the coal and coke industry during 1921. Presents figures and information concerning production, prices, market conditions, exports and imports, for anthracite, coke, briquettes and bituminous coal. Gives miscellaneous transportation statistics of interest to dealers in coal, and discusses export trade.

Dictionary of Applied Physics.

Edited by Sir Richard Glazebrook. Vol. 2. Electricity. Lond., Macmillan and Co., Ltd., 1922. 1104 pp., illus., 9 x 6 in., cloth. $15.00.

The second volume of this important reference work contains many articles of importance to electrical engineers and physicists. Some of the longer articles are: Photoelectricity, by H. Stanley Allen; Technical Applications of Electrolysis, by A. J. Allmand; Arc Lamps, by R. E. Angold; Positive Rays, by F. W. Aston; Insulated Electric Cables, by C. J. Beaver; Switchgear, by R. A. R. Bolton; Capacity and Inductance, by Albert Campbell; Batteries, by W. R. Cooper; Electrons, by J. A. Crowther; Magnetic and Radio-Frequency Measurements, by D. W. Dye; Molecular Theories of Magnetism, by Kotaro Honda; Telephony, by F. B. Jewett; Magnet Design, by R. L. Jones; Stray-Current Electrolysis, by Burton McCullum; Thermionics, by O. W. Richardson and W. Wilson. Numerous bibliographies and a full index are provided.

Elektrotechnik.

Von J. Herrmann. Pt. 1. Die physikalischen grundlagen. Vierte auflage. Berlin, Vereinigung wissenschaftlicher Verleger, Walter de Gruyter & Co., 1922. (Sammlung Goschen.) 125 pp., plates, diagrs., 6 x 4 in., boards.

This is the first of four volumes intended as an introduction to heavy current engineering and is confined to the physical principles involved. The information is presented concisely, definitely and without undue use of mathematics.

Elementary Determinants for Electrical Engineers.

By Herbert P. Few. Lond., S. Rentell & Co., Ltd.; N. Y., D. Van Nostrand Co., 1922. 98 pp., 7 x 5 in., cloth. $1.50.

This material appeared originally as articles in "Electricity," the aim of the writer being to emphasize the advantages that the methods of determinants possess over ordinary algebraic pro-

cesses for solving many types of problems of interest to electrical engineers. Examples are given dealing with testing, telephony, telegraphy, power distribution, cable balancing, etc.

ENGINES AND BOILERS.

By Thomas T. Eyrie. N. Y., The Macmillan Co., 1922. 234 pp., diagrs., 9 x 6 in., cloth. $3.50.

An elementary course in heat engines for students of engineering, based on the author's experience in teaching engines and boilers and allied subjects at Purdue University.

FACTORY STORESKEEPING.

By Henry H. Farquhar. First edition. N. Y. and Lond., McGraw-Hill Book Co., 1922. 182 pp., illus., 9 x 6 in., cloth. $2.50.

The materials considered in this book are the stores or raw materials and factory supplies, and worked materials or work in process and partly or completely finished parts. The book deals with the replenishment, storage and disbursement of these two classes of materials, but excludes the administration of work in process. The book outlines the principles and methods by which this problem may be solved, and a system may be developed to suit local conditions, but does not outline a system for any specific type of factory.

GRAPHIC CHARTS IN BUSINESS.

By Allan C. Haskell. First edition. N. Y., Codex Book Co., 1922. 250 pp., charts, 9 x 6 in., cloth. $4.00.

A companion volume to the author's earlier book, "How to Make and Use Graphic Charts." The present work is confined to the charts most used for business purposes, line, bar, circular percentage, organization, trillinear and probability charts. Methods of making these are explained, their adaptability for various purposes is set forth and their application in various departments of business organizations illustrated. The ratio chart is explained fully. A bibliography is included.

The book is intended to help the man of business see when and how graphic charts can serve his purposes in controlling business operations.

GRUNDZUGE DER ANGEWANDTEN ELEKTROCHEMIE.

Von Georg Grube. Mk. 1. Elektrochemie der Losungen. Dresden und Leipzig, Theodor Steinkopff, 1922. 268 pp., illus., diagrs., 9 x 6 in., paper. $1.68.

The "Principles of Electrochemistry," of which this is the first volume, is intended to meet the need for a brief textbook of practical electrochemistry in which special attention is given to technical applications. The present volume contains the theoretical information necessary for a fruitful discussion of technical electrochemical processes and discusses the electrochemistry of solutions. It includes electrometallurgical processes in solutions, the electrolysis of alkali chloride solutions, electrolytic oxidation processes, the electrolysis of water and electrolytic reduction processes.

HYDRAULICS.

By Horace W. King and C. O. Wisler. N. Y., John Wiley & Sons; Lond., Chapman & Hall, 1922. 237 pp., diagrs., 9 x 6 in., cloth. $2.75.

This book deals with the fundamental principles of hydraulics and their application in engineering practise. Though many formulas applicable to different types of problems are given, it has been the aim to bring out clearly and logically the underlying principles that form the basis of such formulas rather than to emphasize the importance of the formulas themselves. The book is intended as a text for beginners and a reference book for engineers interested in the fundamental principles.

LIQUID FUEL AND ITS APPARATUS.

By Wm. H. Booth. Second edition. N. Y., E. P. Dutton and Co., 1922. 308 pp., illus., diagrs., 9 x 6 in., cloth. $4.00.

The object of this book is to present in a handy form the more practical points of the author's larger book, "Fuel and Its Combustion." The present book is fairly closely confined to the use of liquid fuel under boilers and in internal combustion engines. It discusses the principles of liquid fuel and the properties of fuel oils, gives examples of practise in using oil fuel for stationary boilers, locomotives and oil engines, and discusses burners and the storage, distribution and atomizing of oil.

MASTERING POWER PRODUCTION.

By Walter N. Polakov. N. Y., Engineering Magazine Co., 1921. 455 pp., plates, diagrs., 9 x 6 in., cloth. $5.00.

Contents:—The descent of the principles of production for use.—The power industry as an economic factor.—The location of plants.—The equipment of plants.—Mastering materials.—Mastering maintenance.—Mastering labor problems.—Mastering processes.—Mastering records.—The analysis of expenses.—Power as a commodity.

The subject of this volume is the technology of a method of mastering power production so that the best use of our resources will be made under present social, economic and political conditions. Mr. Polakov avoids discussions of the technical subjects already available in books on power engineering, and confines himself to the broader economic, psychological and engineering features. Special attention is given to management problems.

POWER ALCOHOL.

By G. W. Monier-Williams. London, Frowde, 1922. (Oxford technical publications.) 323 pp., illus., diagrs., 8 x 5 in., cloth. $7.00.

A complete, well-balanced account of all the problems—engineering, chemical and economic—associated with the production and utilization of alcohol as a motor fuel.

PROPERTIES OF ELECTRICALLY CONDUCTING SYSTEMS.

By Charles A. Kraus. N. Y., Chemical Catalog Co., 1922. (American Chemical Society. Monograph series.) 415 pp., diagrs., 9 x 6 in., cloth. $4.50.

Professor Kraus here presents a comprehensive systematic account of the more important conclusions reached by the study of ionic phenomena, which have hitherto been available only in scattered form, in periodicals and transactions of scientific societies. His book affords a convenient summary of the contemporary understanding of the subject, useful both to those directly engaged in studying it and to investigators in allied sciences.

RAILWAY ELECTRIC TRACTION.—

By F. W. Carter. N. Y., Longmans, Green & Co., Lond., Edward Arnold & Co., 1922. 412 pp., diagrs., 9 x 6 in., cloth. $8.50.

This book discusses the methods of electric traction as applied to railways and expounds methods of technical calculation applicable to the subject. In pursuance of the first objective, the author attempts to determine what constitutes good practise and why. The methods of calculation described are for the most part the author's own. The work affords a broad view of the principles underlying electric railways, unencumbered by superfluous descriptive matters.

SIX-PLACE TABLES.

N. Y. and Lond., McGraw-Hill Book Co., 1922. 124 pp., 7 x 4 in., fabrikoid. $1.25.

A selection of tables of squares, cubes, square roots, cube roots, fifth roots and powers, circumferences and areas of circles, logarithms of numbers, logarithms of trigonometric functions, and natural trigonometric functions. Arranged to meet the need for a volume of pocket size containing the tables in regular, continuous use by students and engineers.

SPACE—TIME—MATTER.

By Hermann Weyl. N. Y., E. P. Dutton & Co., 1922. 330 pp., diagrs., 9 x 6 in., cloth. $7.50.

Although many popular introductions to the general theory of relativity have appeared, systematic presentations are not common, and for this reason this translation of the leading German work on the subject is welcome. In it are given all the details of the mathematical reasoning required for a thorough understanding of the subject. The author's extension of the theory to include electromagnetic phenomena is given in full.

TREATISE ON BESSEL FUNCTIONS.

By Andrew Gray and G. B. Mathews. Second edition. Lond., Macmillan & Co., 1922. 327 pp., 9 x 6 in., cloth. $12.00.

This book has been written in view of the great and growing importance of the Bessel functions in almost every branch of mathematical physics; and its principal object is to supply in a convenient form so much of the theory of functions as is necessary for their practical application, and to illustrate their use by a selection of physical problems, worked out in some detail. This new edition has been thoroughly revised. The earlier chapters have been rewritten, examples have been appended and additions have been made to the tables. A bibliography is included.

20TH CENTURY GUIDE FOR DIESEL OPERATORS.

By Julius Rosbloom and Orville R. Sawley. Seattle, Western Technical Book Co., 1922. 637 pp., port., illus., diagrs., 9 x 6 in., cloth.

The authors have attempted to furnish in compact form a summary of present-day knowledge of Diesel engines and their auxiliary machinery. The information given is presented in a form suited to the needs of those in charge of power plants,

and covers both land and sea operation. Many commercial types of engines are described. One chapter is devoted to low compression or "semi-Diesel" engines.

UNTERSUCHUNGEN UBER LAMINARE UND TURBULENTE STROMUNG.

Von L. Schiller. Berlin, Julius Springer, 1922. (Forschungsarbeiten auf dem Gebiete des Ingenieurwesens. Heft. 248) 36 pp., diagrs., 10 x 7 in., paper. 30 Mk.

Gives the results of an exhaustive new investigation of laminar and turbulent flow in pipes, especially of the influence of various factors on the "critical" number. Certain variations from Poiseuille's Law were detected, which had not been noticed by previous investigators, and an explanation is provided for them. In addition to its theoretical importance, this investigation should be of practical value, for it opens the way for the determination of viscosities by means of short tubes and makes possible the determination of absolute viscosity with the well-known Engler viscosimeter.

Addresses Wanted

A list of members whose mail has been returned by the Postal Authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th Street.

1.—Thomas E. Carey, c/o Tel. Co., 1175 Osage St., Denver, Col.
2.—W. S. Guilford, Box 1075, Capetown, S. Africa.
3.—Robert M. Hanscom, 26 Harwood St., Lynn, Mass.
4.—Tadashi Iida, 400 Wilson St., Joliet, Ill.
5.—William Lewis, 31 W. 4th Ave., Huntington, W. Va.
6.—Geo. B. Rodgers, 30 E. 21st St., New York, N. Y.
7.—Robert C. Scott, Box 464, Dundas, Ont., Can.
8.—Hugh H. Wikle, 9547 Calumet Ave., Dauphin Park Sta., Chicago, Ill.

Past Section and Branch Meetings

PAST SECTION MEETINGS

Boston.—October 3, 1922. Joint meeting with the A. S. M. E. Subject: "Gyroscopic Stabilization of Ships." Speaker: Mr. Lea. Interesting discussion followed. Attendance 130.

Chicago.—September 18, 1922. Talk by Mr. Albert A. Northrup. Moving pictures and lantern slides were shown. Attendance 190.

Detroit-Ann Arbor.—September 29, 1922. Business meeting. Dinner and entertainment were enjoyed. Attendance 45.

Indianapolis-Lafayette.—September 29, 1922. Mr. D. J. Angus gave a talk on radio, presenting both theoretical and practical side, and illustrating his talk with demonstrations of his radio set. Attendance 49.

Los Angeles.—September 19, 1922. Subject: "Electrical Safety Orders of the Industrial Accident Commission." Speaker Mr. E. R. Stauffacher. Attendance 45.

Minnesota.—September 25, 1922. Subjects: "Production, Distribution and Use of Bituminous Coal," by Mr. F. H. Rohl, and "Lignite Coal," by H. W. Meyer. A moving picture film entitled "Beyond the Microscope" was shown. Attendance 40.

New York Section.—The first New York Section meeting for the new administrative year, with Chairman Calvert Townley presiding, was held at Engineering Societies Building, New York on the evening of Friday, October 20, 1922. The subject for the evening was one of vital interest not only to engineers but to all residents of New York and vicinity, "The Rail Car, the Trackless Trolley, the Gasoline Bus—Their Respective Fields in City Transportation" by John C. Thirlwall, Engineer, Traction and Transportation Department, General Electric Co. Mr. Thirlwall discussed the relative investment cost and fixed charges on a rail route and its equipment as compared to a gasoline bus installation, and then the relative operating cost per route mile on various headways of the two systems of transportation, showing that while the investment and fixed charges for the busses are very much lower than for the rail route, the operating cost when handling mass business transportation are so much higher for the self-propelled vehicles as to more than offset the other savings. He then discussed the trolley bus as meeting a field in light suburban traffic more economically than do either of the other forms of transport, and showed moving pictures of trolley busses now operating. An interesting discussion followed and was participated in by Commissioner Mills of the Dept. of Plant and Structures, N. Y. City; Edward A. Roberts, Chief of Transportation Bureau, Transit Commission and several others. Attendance was about 300.

Philadelphia.—October 9, 1922. Subject: "National Industrial Standardization," by Mr. P. G. Agnew. There was an informal dinner before the meeting, 21 present. Attendance 50.

Pittsfield.—October 11, 1922. Social meeting. Entertainment and refreshments. Attendance 175.

Portland, Oregon.—October 10. Subject: "Development, Progress and Facilities of the Port of Portland." Speaker: Mr. G. B. Hegardt. Attendance 43.

Providence.—October 6, 1922. Subject: "Evolution of the National Electric Code." Speaker: Mr. F. Elliot Cabot. Attendance 25.

San Francisco.—September 29, 1922. Subject: "The Colorado River Development." Speaker: Dr. W. F. Durand. Attendance 80.

St. Louis.—September 27, 1922. Mr. Frank B. Jewett, President of the A. I. E. E., spoke at length on the work of the A. I. E. E. and its relation to various organizations and committees. Attendance 54.

Schenectady.—October 4, 1922. Subject: "Activities of the A. I. E. E." Speaker: Mr. F. B. Jewett, President of the A. I. E. E. Attendance 200.

Springfield, Mass.—October 3, 1922. Business meeting, and visit to Telephone Exchange. Attendance 27.

Toronto.—September 29, 1922. Subject: "Automatic Telephony." Speaker: Mr. C. D. Schnebly. The operation of the automatic system was explained by use of slides. Attendance 160.

Worcester.—September 28, 1922. Inspection of central office of the New England Telephone & Telegraph Co., after which refreshments were served. Attendance 69.

PAST BRANCH MEETINGS

Armour Institute.—September 21, 1922. Subjects: "The City's Lighting System," by Mr. V. E. Lowden, "Student Engineers at the Western Electric Company," by Mr. E. A. Arentz, "Experiences in a Small Power Plant," by Mr. R. Ruwaldt, and "An Electric Muffle Furnace," by Mr. W. A. O'Brien. Attendance 46.

University of California.—September 6, 1922. Subjects "The Advantages of Belonging to the Student Branch of the A. I. E. E.," by C. R. Brearty, and "The Objects and Policies of the Local Branch," by H. R. Berry. Attendance 64.

September 9, 1922. Inspection trip made to the East Oakland substation and steam plant of the Great Western Power Company. Attendance 25.

September 20, 1922. Subjects: "Electrical Measurements at Telephone Frequencies," by Mr. H. C. Hitchcock, and "The Vacaville Substation of the Pacific Gas & Electric Company," by Mr. F. L. Landon. Attendance 51.

October 3, 1922. Joint meeting with the A. S. M. E., A. S. C. E. and the A. I. M. E. Subject: "National Engineering Problems." Speaker: Mr. L. W. Wallace. Attendance 74.

Carnegie Institute of Technology.—October 5, 1922. Subject: "How to Use a Technical Library," Speaker: Mr. E. H. McClellan, Librarian of the Technology Dept., Carnegie Library. Attendance 37.

Iowa State College.—October 11, 1922. Short talks by members of the Electrical Engineering faculty: Profs. Wood, McClain, Deal, Schilling and Dunlap. Attendance 307.

Kansas State College.—September 25, 1922. Subject: "The Electrical Show at the University of Illinois." Speaker: Prof. Kerchner. Attendance 54.

University of Michigan.—October 11, 1922. Business meeting. Mr. T. W. Younglove appointed Treasurer protem. Attendance 16.

Marquette University.—September 22, 1922. Election of officers as follows: Mr. G. E. Phelps, Chairman, Mr. F. P. Reilly, Vice-Chairman, Mr. P. P. Stathas, Secretary and G. B. Hunt, Treasurer. Future activities of the branch were outlined. Attendance 22.

Notre Dame University.—September 25, 1922. Election of officers as follows: Mr. Vincent J. Brown, President, Mr. Walter F. Rauber, Vice-President, Mr. Walter L. Shilts, Secretary, and Mr. Edward L. Chausse, Treasurer. Attendance 37.

October 9, 1922. Subject: "Science and Philosophy." Speaker: Dr. J. A. Caparo, Dean of Electrical Engineering. Radio concert was given by Messrs. Dooling and de Torrana, and some phenomena of high-frequency currents were demonstrated. Attendance 30.

Ohio Northern University.—September 28, 1922. Subject: "The Benefits of Student Membership in the A. I. E. E." Speaker: Dean Alden. Attendance 25.

October 12, 1922. Business meeting. Attendance 12.

Oklahoma A. & M. College.—September 18, 1922. Subject "The Purpose of the A. I. E. E." Speaker: Prof. W. J. Miller. Attendance 28.

University of Oklahoma.—October 5, 1922. Mr. R. B. Greene elected Secretary. Speakers: Prof. Page, Mr. C. Roush, Mr. I. A. Diffendaffer, Mr. O. B. Reilly. Attendance 10.

Purdue University.—October 3, 1922. Subjects: "Advantages of Belonging to the A. I. E. E.," by Prof. C. F. Harding, "Different Kinds of Membership in A. I. E. E.," by Prof. A. N. Topping. Short talks by Prof. J. B. Nailey and Dean A. A. Potter. Refreshments were served. Attendance 124.

October 10, 1922. Subject: "Activities of the National Electric Light Association," by Mr. T. N. Wynne. Attendance 54.

School of Engineering, Milwaukee.—October 11, 1922. Election of officers as follows: Mr. M. J. Maiers, Chairman, Mr. E. Webb, Vice-Chairman, Mr. R. Schrodt, Treasurer, Mr. J. P. Gibbons, Secretary. Mr. Maiers reviewed the Milwaukee Branch activities and history. Attendance 25.

Syracuse University.—September 26, 1922. Election of officers as follows: Lester E. Angwin, Chairman, Lloyd E. Lawrence, Secretary. Subject: "Aims and Possibilities of the Branch," by Prof. Rich D. Whitney. Attendance 12.

Virginia Military Institute.—October 6, 1922. Subjects: "Regenerative Braking," by Mr. H. B. Barrow, "Gas Engine Ignition," by Mr. R. H. Pretlow, "Automatic Train Control," by A. W. Belden, Jr., "The Coal Situation," by Mr. A. S. Briggs, Jr. Attendance 39.

University of Wisconsin.—September 27, 1922. Subject: "Advantages of Membership in the A. I. E. E." Speaker: Prof. T. A. Rood. Attendance 44.

October 11, 1922. Business meeting. Attendance 21.

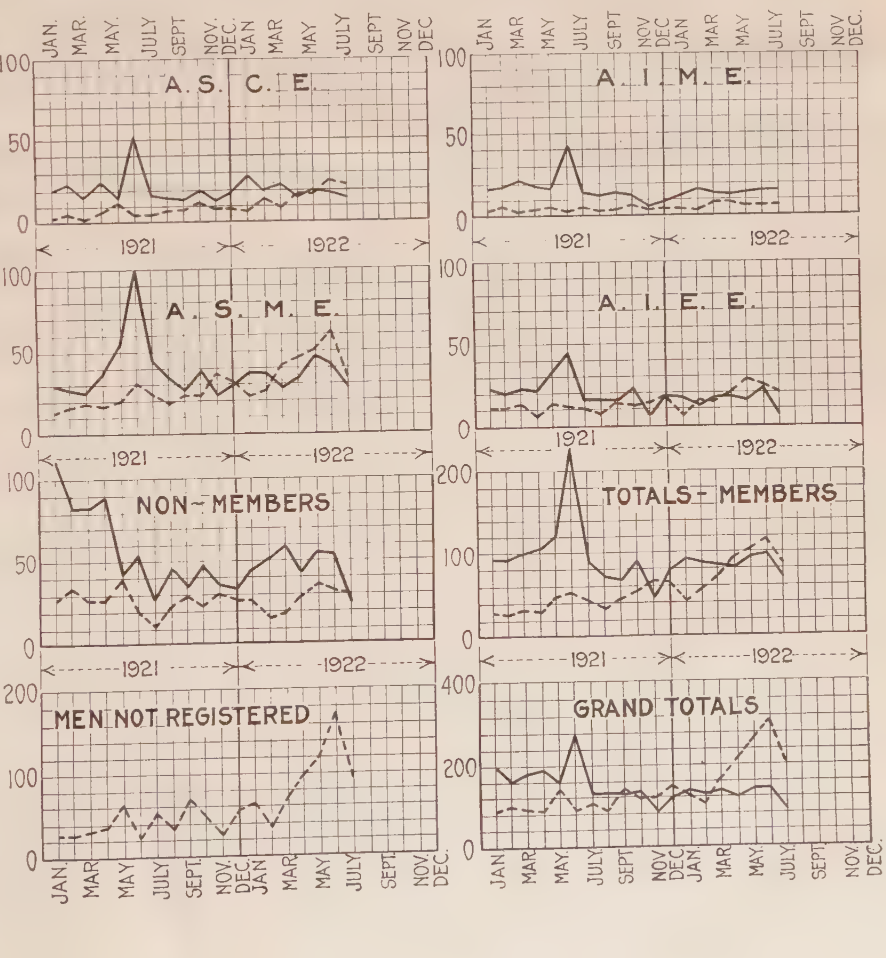
Engineering Societie's Employment Service

The cut shown give some interesting statistics on the employment situation as well as some information concerning the function of the employment service. The service is conducted jointly by the four National Engineering Societies. Separate data are plotted for each of these societies. In each case the full line curves represents the number of men registered by months. The dotted curves represent the number of men who are known to have obtained positions. Many men obtain positions through the service which are never reported. The curve of placements of "men not registered" represents to a large extent men who have obtained positions through the "positions available" columns and whose names are not reported by the employer.

Since October 1st, 1922, non-members have been dropped from the lists.

It is interesting to note that the trend of the registrations is generally downward and the trend of placements is generally upward. The Spring of 1922 appears to have been a critical period as most of the curves cross at that point and are holding to those gains in spite of the effect of the coal and railroad strikes.

This service, only one of the many society activities, is a great benefit to many members throughout the country, and distinctly shows one manner in which the value of membership in a National Engineering Society has enhanced during the last year.



Employment Service Bulletin

OPPORTUNITIES.—Desirable opportunities for service from responsible sources are announced in this Bulletin, and no charge therefor is made.

MEN AVAILABLE.—Under this heading brief announcements will be publishedwithout charge to the members. Announcements will not be repeated except upon request received after a period of three months, during which period names and records will remain in the active files.

NOTE.—Notices for the JOURNAL ***should be addressed to EMPLOYMENT SERVICE, 33 West 39th Street, New York, N. Y.,*** *the employment clearing house of the National Societies of Civil, Mechanical, Mining and Electrical Engineers.*

Notices for the JOURNAL are not acknowledged by personal letter, but if received prior to the 16th of the month will appear in the issue of the following month.

All replies to either "Opportunities" or "Services Available" should be addressed to the key number indicated in each case ***and forwarded to EMPLOYMENT SERVICE,*** *as above.*

Replies received by the bureau after the position to which they refer has been filled will not be forwarded, and will be held by the bureau for one month only.

OPPORTUNITIES

ELECTRICAL ENGINEER for remote control and substation design. Must be thoroughly familiar with use of relays. Must be Electrical Engineering graduate, under 45 years of age. Full details of education, experience, salary and time available should be given in first letter. Location, Pa. V-43.

DRAFTSMAN for checking electrical drawings, wiring diagrams, etc. Must be Electrical Engineering graduate, under 45 years of age. Full details of education, experience, salary and time available should be given in first letter. Location, Pa. V-44.

SALES ENGINEER. Young single man having practical experience with detail electrical switchboard apparatus, such as circuit breakers and instruments. Sales experience not necessary. State age, experience and salary expected. Location, Philadelphia territory. V-1683.

YOUNG GRADUATE ENGINEER with some experience on fire prevention work preferably with one of the larger industrial insurance companies. Location, New York City. Application by letter. V-1860.

FOREMAN. Dry press shop. At present department employs 40-50 persons. Must have had experience in dry-pressing of porcelain. Position eventually leads to superintendency of plant. Age 30-35; technical education not essential, but experience is. Application by letter. Salary depending on experience of applicant. Location, Ill. V-2179.

ELECTRICAL ENGINEERING GRADUATES with two to five years experience on central and substation designing, switchboard diagraming and drafting. Salary according to experience and ability. Application by letter stating age and attach photograph. Location, Pa. V-2193.

HIGH CLASS ELECTRICAL SALES REPRESENTATIVES for reliable concern manufacturing carbon graphite, electro-graphitic and metallic brushes for motors and generators, also general lines of carbon specialties. Exclusive rights given to each of territories on liberal straight commission sales proposition. Specify in detail past engineering and sales experience. Territories Chicago vicinity, St. Louis, Birmingham, Mexico, Montreal and San Francisco. Headquarters, N. Y. V-2184.

GRADUATE ELECTRICAL ENGINEERS (2) or DESIGNING DRAFTSMEN, with 2-5 years experience on electrical apparatus, such as substations and switchboard designing, public utilities organization. Application by letter. Location, Penna. V-2193.

DESIGNING ENGINEERS (6) graduate Electrical engineers required for substation and switchboard designing, public utilities central station work. Application by letter. Location, Penna. V-2194.

DESIGNING DRAFTSMAN, graduate Electrical Engineer. Must be good letterer. Send sample of drawing with application, central station. Application by letter. Location, Penna. V-2195.

APPRENTICE AND ASSISTANT TEST ENGINEERS, Mechanical Engineering graduates, for testing turbines, pumps, condensers. Central station plants. Application by letter. Location, Penna. V-2196.

YOUNG ENGINEER E. E. or M. E. experienced in the use and application of auxiliary for high pressure modern steam power plants. Ability to write advertising copy and prepare technical articles for press essential. Company manufactures electrical valve control equipment used exclusively on steam lines in large power stations and also complete line of valve control apparatus for water works and power stations. Will also act as research engineer for new fields for control and must possess sufficient business and engineering knowledge to carry on work without supervision. Prefer married man, age not over 35 or 40, already in a similar position. Application by letter. Salary not stated. Location, Conn. V-2302.

ELECTRICAL ENGINEER experienced on detailing generator foundations, electrical leads, conduits, etc. Must be able to make good drawing. Application in person. Location, Alabama. V-2326.

ELECTRICAL ENGINEERS or MECHANICAL ENGINEERS (2) with sales experience and preferably G.E. testing floor experience to handle sale of carbon brushes. Will be given three months training course at factory in Middle West. Clean-cut Americans of 30 years and good personality desired. Application by letter. Salary not stated. Location not stated. V-2354.

SUPERVISOR FOREMAN, one who can take charge of all kinds of power, high and low pressure, heating and ventilating. Position involves considerable technical knowledge together with the ability to handle men and get results. Application by letter. Salary not stated. Location not stated. V-2435.

COMBUSTION AND SALES ENGINEER. Sales work most important. Acquaintance with New York City and state of New Jersey. 30-37 years old. Application by letter. Salary depends on man. Location, New York City. V-2437.

YOUNG MAN, college graduate in engineering, preferably one who has had a year or so experience working. Should have qualifications to make a good salesman, be able to speak Spanish and be willing to spend, if necessary, nine months of the year travelling in Cuba. Application by letter. V-2438.

DRAFTSMAN for conveyor company specializing in package and box conveyors and sheet metal spiral. Must have this experience. Application by letter giving experience. Salary not stated. Location, Ohio. V-2440.

CHIEF DRAFTSMAN to take charge of details. General structural steel experience and also some power house experience. Application in person. Location, N. Y. V-2434.

CONSTRUCTION ENGINEER specializing in line of oil mills for extracting oil from olive husks by means of carbon sulphide (or any other solvent that gives better results than sulphide), including installations of soap plant, complete refinery (neutralization, deodorization and decoloring). Application by letter. Salary not stated. Location, Mahdia, Tunis. V-2458.

CIRCUIT LAYOUT DRAFTSMAN experienced on control and switchboard circuits. 21-30 years old. Application in person. Location, New York City. V-2471.

ENGINEERING REPORT CLERKS to compile charts showing job progress. Application in person. Location, New York City. V-2472.

TECHNICAL INVESTIGATOR to have field contact with job foreman. Clean-cut American, college graduate with tool and shop production experience 24-35 years old. Application in person. Location, New York City. V-2474.

DESIGNERS. Technical men familiar with turbine or steam engine practise preferred. Only rapid, thorough workmen need apply. Application by letter giving experience, age and minimum salary expected. Location, Philadelphia, Pa. V-2478.

RECENT GRADUATES (4), Mechanical, Chemical or Electrical, to take course of training for industrial fuel (gas) representatives. Must have a personality and desire for sales work. Application in person by phone. Location, N. Y. V-2477.

YOUNG MECHANICAL ENGINEER with training in economics as well as engineering. Practical experience in factory production and management essential, also sympathetic understanding of American labor movement. Desired for research and preparation of briefs, reports, exhibits, etc., chiefly in field of industrial relations. Application by letter submitting complete statement of qualifications. Salary not stated. Location, New York City. V-2498.

ELECTRICAL ENGINEER for teaching disabled soldiers. Traveling position in New York, Conn. and N. J. Later on will be required to take Civil Service examination. Application by letter. Headquarters, New York City. V-2507.

DESIGNER for turbine, switchboards, R. R. motor, etc. Must be experienced man. Application by letter stating age, education, experience, etc. Salary not stated. Location, New York State. V-2512.

SALES ENGINEER, young, single man having one or two years practical experience for exploiting sale of a line of industrial equipment in New England and Middle Atlantic States. Application by letter stating age, experience and salary expected. Headquarters, New York City. V-2517.

ENGINEERING SALESMAN. Good opportunity for young electrical engineering graduate to establish with a large electrical manufacturing concern as a sales engineer. Application by letter stating important particulars in first letter. Salary not stated. Location, Central. V-2526.

ENGINEER EXPERT on automatic machinery for new development on recoil mechanism of big guns. Application by letter. Salary not stated. Location New York State. V-2532.

DESIGNER. Young man preferably with actual d-c. design experience who is willing to adapt himself to company's methods of designing. Application by letter. Location, New Jersey. V-2534.

ENGINEER with advertising or catalog writing experience. Application by letter stating age, education and experience in detail. Salary not stated. Location, New York State. V-2548.

MECHANICAL ENGINEER for power test work. Should be graduate of good engineering school, and should have had not less than two years experience in power testing, including boiler tests, motor tests, measurement of steam,air and water flow. Should preferably be familiar wtih good power plant practise both mechanical bod electrical in small industrial plants containing boilers, engines, generators, air compressors, and reirigerating machinery. Must be able to co-operate with plant superintendents and staffs. Will be temporarily stationed at plants where opinions must have sufficient weight to obtain respect. Considerably traveling involved. Work will consist of power testing and investigation to determine methods for obtaining highest operating economy for least expenditure. Prefer unmarried man. Salary depends on qualifications. Application by letter giving complete qualifications. Location, Delaware- V-2554r

ELECTRICAL LABORATORY INSTRUCTOR with several years dynamo laboratory experience, or equivalent. Work will be done in afternoons and evenings, no morning work or Saturday work required. Application by letter. Location, Pa. V-2558.

DRAFTSMAN experienced in design and detail of electric switchboards and switch gear, to take charge of drafting room in rapidly growing manufacturing corporation. Application by letter. Salary not stated. Location, Philadelphia, Pa. V-2560.

SALES ENGINEER, preferably between 30 and 40 years of age, with experience in sale of foundry equipment, to act as district representative. Right man can make very profitable connection. Application by letter. Salary not stated. Location, Cleveland, Ohio. V-2561.

BATTERY MAN to do repairing and recharge-ing of all makes of batteries. At least one year's experience. Application in person. Location, New York City. V-2568.

COST CLERK competent to keep track of cost of production of sugar in raw sugar factory that has in conjunction with it a refinery and distillery. Living quarters provided if married, and room to live in if single. Would have to purchase food or board. Cost of food or board would be somewhat less than if purchased in New York City. Will be sent to plant sometime in November. Application by letter. Headquarters, N. Y. C. Location, Phillipine Islands. V-2573.

SALES ENGINEER for chemical machinery. Some knowledge of chemistry required. 25-30 years of age with some experience. Application by letter. Salary moderate at start. Location, New York City. V-2574.

ENGINEER experienced in the design, operation and sale of insulating materials in connection with installations of all forms of drying apparatus such as textile dryers, centering frames, leather dryer, dryers used in chemical processes and will also enter field of japanning ovens as used in automobile and metal industry. Must have had thorough sales experience in addition to the necessary technical training. Application by letter stating age, education and experience in detail. Salary not stated. Location, Pa. V-2576.

ENGINEERS AND DRAFTSMEN for central officers engineering division for men with college training in engineering or the physical sciences. Practical telephone experience may substitute. Draftsmen who have had technical high school training and 2-4 years drafting experience. Application by letter. Salary not stated. Location, Illinois. V-2578.

EXPERIENCED RELIABLE SERVICE MAN for small commercial refrigerating machines. Application by letter. Salary not stated. Location, New York State. V-2589.

SALES ENGINEER, mechanical with several years experience with small pumps. Age under 30. Application by letter. Salary not stated. Location, New York City. V-2591.

DRAFTSMEN experienced in high tension substation design, structural and concrete experience desired. Permanent position with good chance for advancement. Application by letter giving full details. Salary not stated. Location, Southwestern Ohio. V-2594.

ENGINEER, 30-35, to sell oil storage and oil burning equipment in North Eastern territory. Must be broad gage engineer with general industrial plant experience and preferably sales experience. Application by letter. Salary $2400 and commission. Location, New York City. V-2596.

MECHANICAL ENGINEER with experience in designing valve gears for steam engines. Application by letter. Salary not stated. Location, San Francisco, Calif. V-2599.

JUNIOR SALES ENGINEER. Must be technical graduate and preferably have a little experience either drafting or building steam specialties. Must have good address and appearance. Work will be mainly missionary. Application by letter. Location, Pa. V-2600.

EXPORT SALESMAN of electrical appliances. Actual engineering knowledge not required but thorough knowledge of the export merchant, export commission house and foreign selling. Good live wire with pleasing personality and sales ability. Application by letter. Commission basis. Location, Toledo, O. V-2604.

STRUCTURAL STEEL DRAFTSMAN experienced on ornamental and light steel work. Application in person. Location, Long Island, N. Y. V-2616.

DRAFTSMAN familiar with power plant, water supply and architectural work. Must speak Spanish. Application by letter. Salary not stated. Location, S. America. V- 618.

OUTSIDE M. E. ENGINEER who can put in overhead work and lay track and familiar with track bonding bridge, etc. Must speak Spanish. Application by letter. Salary not stated. Location, South America. V-2620.

CHIEF DRAFTSMAN to take charge of drafting office. Must speak Spanish. Application by letter. Salary not stated. Location, South America. V-2621.

DRAFTSMAN with water wheel experience. Age between 35-45. Need not necessarily be a technical graduate. Application by letter. Location, Mass. V-2625.

SALES ENGINEERS (6) and 4 junior Sales Engineers to sell fuel oil burners and oil burning systems. Application in person by appointment. Salary not stated. Location, Brooklyn and Long Island. V-2628.

YOUNG DRAFTSMAN who is looking for experience and opportunity for advancement. Want man that can be trained to fill a responsible position. Application by letter. Interview New York, Philadelphia, Chicago, and San Francisco. Salary not stated. Headquarters, Philadelphia, Pa. V-2630.

ENGINEER with business ability, capable of taking complete charge of a business consisting of design, construction, and installation of tube boilers for large power plant service. Application by letter. Interview New York, Philadelphia, Chicago, and San Francisco. Salary not stated. Headquarters, Philadelphia, Pa. V-2631.

EXPERIENCED SALESMAN to sell boilers. Application by letter. Interview New York, Philadelphia, Chicago, and San Francisco. Salary not stated. Headquarters, Philadelphia. V-2632.

ENGINEER with experience in manufacture of loose-leaf books. Manufacture of a pocket book contemplated. Want man capable of starting necessary plant and taking charge of operations. Application by letter only. Salary not stated. Location, Pa. V-2633.

ENGINEER to write articles dealing with economic, political and social problems of the day. Must be capable of writing original articles that will interest intelligent people of all classes and secure attention of engineers, business men, educators and statesmen. Application by letter only. Salary not stated. Location, Pa. V-2634.

ENGINEERS capable of gathering information needed in different branches of engineering and putting it in most concise form for publication in bound books to be used in conjunction with loose leaf service. Application by letter only. Salary not stated. Location, Pa. V-2635.

STRUCTURAL STEEL DRAFTSMEN, or draftsman familiar with reinforced concrete work. Application by letter. Salary not stated. Location, South Carolina. V-2639.

SALESMEN (2). Age 25-28. Will be sent to factory for course of training before going on road. Prefer unmarried men willing to live in some other city, either as District Manager or Assistant to District Manager. Application by letter. Salary $1,200 per year to start, during course of training, after that commensurate with position. Headquarters, New York City. V-2641.

DESIGNER for steam and electric power plants, transmission lines and hydroelectric structures. Able to write specifications. About 36 years old. Application by letter. Location, New York City. V-2643.

STREET RAILWAY ENGINEER between 35-45 years of age having had some technical education and a number of years practical experience in actual operation of all classes of street railway rolling stock. Application by letter giving education, experience, age and salary desired. Location, New York City. V-2652.

STRUCTURAL DRAFTSMEN (10). Salary according to qualifications. Location, New York City. Application by letter. V-2654.

MANUFACTURER of constant potential battery charging systems for battery service stations, has several districts open for agencies and desires to hear from men experienced in sale of battery equipment and having acquaintance in the trade. Application by letter. Salary not stated. Headquarters, Chicago, Ill. V-2660.

YOUNG ENGINEER to start as time keeper or material clerk with large construction company who is developing a field organization. Application by letter stating age, education and experience. Salary not stated. Location, New York City. V-2661.

MINE BLACKSMITH at feldspar quarry to sharpen jack-hammer steel. Permanent position. Application by letter. Salary for nine hours work, rate 60-70 cents per hour. Location, Middletown, Conn. V-2662.

SALESMEN (5) to sell patent covering for pulleys. Application in person. Commission basis. Headquarters, New York City. V-2664.

EXPORT SALES REPRESENTATIVE for company manufacturing nestable culvert. A man representing other company who has his own office and would be interested to add other products to his present line desired. Application in person. Salary not stated. Location not stated. V-2668.

PLATER experienced in continuous process of coating fine wire. Must have sufficient knowledge of chemistry to make own formulas. If applicant has executive experience there is an opportunity to become interested in the business. Application by letter. Salary not stated. Location, Mass. V-2670.

SALESMAN for electrical supply and construction work capable of assisting manager and training for position of manager. Rapid advancement assured for right man. Application by letter. Salary not stated. Location, Utica, N. Y. V-2674.

ELECTRICAL ENGINEER familiar with central station and high tension apparatus, Must have construction experience as well as designing ability. Capable of taking charge of work in the

field. Application by letter. Salary not stated. Location, Michigan. V-2677.

STENOGRAPHER, secretary and general assistant to manager of several electric light and water properties in New Jersey. Excellent position with unlimited field for advancement. Do not apply unless thoroughly experienced and competent. Man preferred but not essential. Living conditions excellent. Application by letter. Salary not stated. Location, New Jersey. V-2688.

YOUNG SALES ENGINEER in correspondence section sales department of electrical manufacturer, preparing bids and handling correspondence. Knowledge of motors and transformers essential. Will lead to direct sales work in short time. Apply by letter giving qualifications and salary expected. Headquarters, St. Louis. V-2706.

ASSISTANT LABORATORY ENGINEER in the laboratory of an electrical manufacturing concern in New England. The man will handle to a large extent, electrical and physical measurements connected with manufacturing and testing problems. A good deal of development work on special test devices will be necessary. The opportunities for advancement are excellent. A man with at least two or three years electrical laboratory experience is desired. V-2710.

A large manufacturer's laboratory has several openings for men for test positions. The opportunities for advancement for properly trained men are very good. The work is along the lines of electrical and physical measurements, and may include a considerable amount of development. Men desired are of age, and technically trained. They should have some electrical laboratory experience or experience on meter or instrument work. V-2711.

ELECTRICAL ENGINEER, technical graduate with 8-10 years experience to supervise design of substations, generating stations and transmission lines for power company with something over 150,000 kw. and several hundred miles of transmission on its system. Application by letter. Salary not stated. Location, New York State. V-2739.

MEN AVAILABLE

ELECTRICIAN. Sixteen years experience installation and maintenance d-c. and a-c. equipment, also cranes. Past eleven years chief electrician large industrial plant. Age 37. Married, Assoc. A. I. E. E. Prefer location East. E-3972.

GRADUATE ENGINEER, B. Sc. in Mechanical Engineering, enrolled Student of A. I. E. E. Would like to work with pumping machinery or internal combustion engines for power purpose. Opportunities for the future. Location near Chicago. E-3973.

ELECTRICAL ENGINEER with ten years experience designing alternating current apparatus (transformers, motors and special apparatus) desires position as designing engineer or engineering executive. Special qualifications include energy, technical knowledge, knowledge of manufacturing methods, business ability and ability to cooperate with and direct others. Only position of responsibility considered. E-3974.

SALES ENGINEER, age 30, E. E. degree, also graduate of two well known business institutions. Has had both engineering and sales experience. Affiliation with progressive organization desired. E-3975.

EXECUTIVE ENGINEER OR ASSISTANT MANAGER. Graduate electrical and mechanical engineer, age 33, experienced in construction, operation, maintenance, organization, appraisal engineering, steel mill operation and machine shop practise. Business experience. Have executive ability and can handle men. E-3976.

TECHNICAL GRADUATE. Young man who earned his college education would appreciate an offer from any organization which will give him an opportunity to prove his ability. Location in the middle west desirable, but not essential. At present employed. E-3977.

TO A HIGH GRADE MANUFACTURER OF MECHANICAL EQUIPMENT we offer a corresponding sales-engineering service with intensive personal attention. Pittsburgh District. E-3978.

MECHANICAL SUPERINTENDENT, technical graduate. Age 40, married. Eighteen years experience in power plant operation; ten years of the time with large cotton mills as master mechanic. Expert on combustion, both oil and coal fuels. Have designed and installed complete electric drive for large mill. Present position requires being away from home too much of the time. Member A. I. E. E. E-3979.

I. C. S. ELECTRICAL ENGINEERING STUDENT, 24, single, desires starting position with electrical power, light or manufacturing concern in New York City or near suburbs. E-3980.

AN ENGINEER AND FACTORY EXECUTIVE of nineteen years business and engineering experience; manufacturing, designing, executive and sales work; seven years college training. Experience covers motors, controllers, secondary batteries, material handling machinery and domestic appliances. Available in thirty days as manager, chief engineer, plant engineer, sales engineer, or assistant. Salary $6000. E-3981.

ELECTRICAL ENGINEER, technical graduate, desires connection with central station, in New England states or New York. Has had experience in meter work and high tension equipment, has executive ability and can handle men. Assoc. A. I. E. E. Age 29, available one month. E-3982.

ENGINEER, good executive, familiar with costs, layout work, estimating and construction of electrical, steam, water and sewerage systems desires position in charge of construction. Thoroughly familiar with modern construction methods both in office and field. E-3983.

SALES ENGINEER with live organization covering New England desires to represent additional manufacturers of electrical equipment in this territory. E-3984.

PLANT ENGINEER, American, 34, married, graduate E. E., efficient, clear thinking and industrious; possesses initiative and ability, 12 years experience in power plant construction, electrical installations and industrial power layouts. Prefer location in eastern or central states but will consider other offers. Available after Nov. 15. Assoc. A. I. E. E. E-3985.

YOUNG ELECTRICAL ENGINEER, 1922 graduate of Brooklyn Polytechnical Institute wishes to connect with an electrical contracting firm or small electrical manufacturing concern. Opportunity to advance sought first. E-3986.

TECHNICAL GRADUATE OF ELECTRICAL ENGINEERING, evening course, 1921, from Cooper Union Institute, seeks a position, in technical, sales or other responsible capacity. Have five years of good practical experience in switchboards, public utility, motor and generators as a draftsman, tester and shopman. Age 25. Available at once. E-3987.

ELECTRICAL ENGINEER. Three years General Electric test. Twelve years practical experience engineering, executive sales, including substation, powerhouse and switchboard design. Manager construction company four years, installing all kinds electrical apparatus. Age thirty-four, married, family. Desires permanent position. Best references. E-3988.

ELECTRICAL ENGINEER, graduate 1922, sales and practical experience, desires to locate with a sales or illuminating engineering company, that offers a chance for advancement in the future. Location unimportant. E-3989.

ELECTRICIAN-MECHANIC, 8 years experience in electrical construction and maintenance of electrical machinery to take charge of maintenance in large plant. A. I. E. E. Vicinity New York City. E-3990.

MECHANICAL AND POWER ENGINEER, technical graduate, B. S. and M. E., eight years broad experience, machine shop, metallurgy, sugar engineering, industrial and power plant practise, operation, design, layout, calculations, heat balance, utilization and distribution of steam, water, coal, power, etc., investigation, research, reports. Executive and business ability. E-3991.

ELECTRICAL ENGINEER, technical graduate, Assoc. A. I. E. E. Age 28, single. Two years General Electric Test, one year mines electrician, four years hydroelectric construction, operation and management. Desires opportunity as executive or inspector. Any location. Available immediately. Present Salary $2000. E-3992.

GRADUATE ELECTRICAL ENGINEER, M. I. T. 1921, 25, married, desires position with electrical construction firm. Have designed and installed hydroelectric power plant and distribution system. Experience in reinforced concrete work. Can handle men. One and a half years with A. T. and T. Co. $2000 expected, opportunity for advancement prime consideration. References. E-3993.

ENGINEER, desires to enter employ of consulting engineer. Experience includes nine years of factory test and road work with large manufacturer on all classes of electrical apparatus, also some work on steam turbines. Now employed. Age 31, married. Assoc. A. I. E. E. Can be of real value to right man. E-3994.

1919 GRADUATE, Cooper Union B. S. in E. E., Associate A. I. E. E., two years testing experience on d-c. machinery, 3 years as electrician on light and power installations, age 25, single, desires position with public utility or mining corporation, outdoor work preferred but not essential, location immaterial. E-3995.

GRADUATE ELECTRICAL ENGINEER, Associate A. I. E. E. with nineteen months G. E. test and one year construction work desires position with power company. Location, Pacific Coast. Age 28, single. E-3996.

GRADUATE ELECTRICAL ENGINEER, married, age 27 years, two years experience, at present employed in large industrial concern desires to secure position with smaller concern where chances for promotion are more rapid. Starting salary $150 per month. Location desired, central states. At present Associate A. I. E. E. E-3997.

RADIO ENGINEER, Assoc. A. I. E. E. and I. R. E. desires position with radio research or manufacturing concern either in U. S. A. or any foreign country. Five years radio experience, two in French army and three with large electrical company New York City. Graduate E. E. from school of high standing. Thorough knowledge of English and French. Recently engaged in developing and designing broadcasting transmitters and receivers, radio frequency amplifiers. Expert in radio measurements of all kinds. Age 32, married, salary wanted $300 a month. Available at once. E-3998.

SALES ENGINEER. 5 years experience in commercial and operating phases of metal industry. Rolling mill and technical departments of large corporation for past 3½ years. American. 29 years old, married. E-3999.

EXECUTIVE, graduate electrical engineer with 23 years' experience in the construction, operation and management of utilities. Thoroughly familiar with electric and ice properties and central station heating. Prefer middle west or Pacific coast. E-4000.

ASSISTANT ELECTRICAL SUPERINTENDENT INDUSTRIAL PLANT, technical education, married, age 30, familiar with electrical, mechanical construction and operation, lighting and power layouts for power house and industrial plants. Location Chicago or immediate vicinity. E-4001.

ASSISTANT COMMERCIAL ENGINEER. Assoc. A. I. E. E. Age 33. Ten years' experience in railway, light and power work, both commercial and operating. Completed Westinghouse Graduate Students' Apprentice Course, East Pittsburgh, Pa. Desires position as Assistant Commercial

Engineer, or position leading to it, with public utility. Now with large power company. E-4002.

SALES ENGINEER, 28, single, college graduate, with test, construction, and head office sales experience wants active position as sales or merchandising engineer, salary $200 per month. E-4003.

MECHANICAL-ELECTRICAL ENGINEER, University graduate, one year G. E. Test, two years power plant efficiency engineer, eight years power engineer for steel company, three years electrical cable engineer including commercial work. Member A. I. E. E. and A. S. M. E. Desires position as mechanical or electrical superintendent. E-4004.

TECHNICAL GRADUATE E. E. Assoc. A. I. E. E., age 28, single. Fourteen years practical electrical experience. Last 4 years had charge of electrical construction and maintenance department. At present taking evening course on power plants and steam engines. Desires position with power or industrial plant. E-4005.

YOUNG MAN, 22, three years electrical laboratory experience for large power company desires position with engineering firm. Specialized testing and analyzing test results of electrical equipment in factories. Will graduate electrical engineering March 1923 at evening technical school. Want position with opportunity for promotion preferably in southeastern Pa. E-4006.

YOUNG MAN, 24, graduate E. E. 1921, wishes to break in on manufacturing or testing. At present employed, but a change will be made. Position offering some opportunity desired. E-4007.

ELECTRICAL DRAFTSMAN, age 24; 5 years experience in hydroelectric power plant and outdoor substation layout and design, desires position as electrical draftsman preferably in consulting engineer's office where opportunity for advancement can be had in exchange for hard and conscientious work. At present employed by a power company in California. E-4008.

ELECTRICAL MAINTENANCE AND CONSTRUCTION FOREMAN. Ten years experience on power switch boards, automatic control, electric locomotives, cranes and elevators, motors, generators, etc. Three years G. E. test, 2 years service station in shop and on road. Can handle men. Age 32. Desires position with some power company or growing industry. E-4009.

1922 GRADUATE with advanced degree in electrical engineering and experience in public utility operating, gained during summer vacations, desires position with consulting engineer or contractor. E-4010.

PUBLIC UTILITY CONSULTANT. Technical graduate, experienced on valuations, rates and commission practise, desires to locate with consulting firm, public utility or financial institution. Location preferred, Philadelphia. Age 34, married. E-4011.

ELECTRICAL ENGINEER, age 28, single graduate civil engineer. Completed electrical engineering course at Columbia University, New York City. Seven years experience in electrical testing and maintenance of relay and watt hour meters. Familiar with electrical railway, design and construction. Can supply references. Desires permanent position in Cuba with electrical concern. E-4012.

ENGINEERING EXECUTIVE, long experience with high voltages, power transmission, hydroelectric installations, design, construction, management, desires responsible position along similar lines or would act as consultant. Fourteen years with last connection on various large power propositions, holding leading positions from engineer to general manager. E-4013.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED OCTOBER 9, 1922

ACKERMAN, ROGER OSBORNE, Power & Mining Engineering Dept., General Electric Co.; res., 16 Front St., Schenectady, N. Y.

ADLER, CHARLES, Jr., Signal Engineer, Maryland & Pennsylvania Railroad Co.; res., 1718 Eutaw Place, Baltimore, Md.

ANDERSON, EDWARD THEODORE, Assistant Electrical Engineer, United Light & Railways Co., Davenport, Iowa; res., 3449-7th Ave., Rock Island, Ill.

*ANDERSON, GORDON ROWEN, Electrical Engineer, Fairbanks, Morse & Company, Indianapolis, Ind.

BAGGHI, SUDHIR KUMAR, Electrical Foreman, in charge M/S Shop No. 2, Tata Iron & Steel Co., Ltd., 97 Q Road West, Jamshedpur, India.

BALSARA, JALEJAR NAORAJI, Electrical Engineer, Bombay Steam Navigation Company; res., 10, 2nd Carpenter St., Mazgaon, Bombay, India.

BARRETT, WILLIAM REGINALD, General Line Foreman, Utah Power & Light Company, 133 South West Temple, Salt Lake City, Utah.

BARRINGER, EDWIN WALTER, Electrical Engineer, Barringer & Gyde; res., 17 Surre St. Hawera, New Zealand.

BASAK, JAGAT DURLAB, Electrician, Tata Iron & Steel Company, Ltd., 49, P Road, Jamshedpur P. O., via Tatanagar, India.

BEDORF, ALBERT FRED, Foreman, System Regulation Section, Duquesne Light Company, 3708-5th Ave., Pittsburgh, Pa.

BERGENDAHL, RUDOLPH, Telephone Equipment Engineer, Automatic Electric Company; res., 7215 Langley Avenue, Chicago, Ill.

BISEK, PETER PAUL, Assistant Superintendent, U. S. Reclamation Service, Power Plant R No. 1, Williston, N. Dakota.

BLOOM, FRANK ANDREW, Chief Electrician, Fletcher Paper Company, Alpena, Mich.

BORDEN, DOUGLAS CLARE, Switchboard Wireman, Hydroelectric Power Commission of Ontario, Queenston Station; res., 62 Mountview Ave., Toronto, Ont.

BOUCHARD, MARION J., Sales Engineer, Electric Storage Battery Co., Washington, D. C.

BOUCHER, JAMES FINLEY, Power House Superintendent, The Spanish River Pulp & Paper Mills, Ltd., Smokey Falls Plant, Sturgeon Falls, Ont.

*BOWLES, EDWARD LINDLEY, Teacher of Electrical Engineering, Mass. Institute of Technology, Cambridge, Mass.

BOWLEY, JOSEPH WILLIAM, Head of Department of Electrical Engineering, Keystone Institute, Reading, Pa.

BROKAW, JAMES BARTON, Division Manager, Eastern Oregon Light & Power Company, La Grande, Ore.

BULL, HEMPSTEAD STRATTON, Department of Electrical Engineering, University of Michigan, Ann Arbor, Mich.

CAPLAIN, PHILIP, 1561-52nd St., Brooklyn, N. Y.

CECCHINI, JOSEPH P., Chief Electrician, Sheridan-Wyoming Coal Company, Monarch, Wyoming.

CHACON, FERNANDO EUGENE, Mining Dept., Braden Copper Co., Rancagua; Casilla 1557, Santiago, Chile, S. A.

CHILDS, HENRY WILLIAM, Electrical Contractor & Borough Engineer, Council Chambers, Kaiapoi, N. Z.

COLL, ERNEST A., Superintendent, Substations, Porto Rico Railway, Light & Power Company, San Juan, P. R.

COUTTS, HAROLD LESLIE, Electrical Engineer, Pardee Steel Corp., Perth Amboy; res., 549 Maple Ave., Woodbridge, N. J.

COY, J. ALMON, Telephone Engineer, American Tel. & Tel. Company, 195 Broadway, New York, N. Y.; res., 6 N. 21st St., E. Orange, N. J.

CREE, GEORGE GAULT, Lighting Dept., General Electric Company, Schenectady, N. Y.

CROOK, ROBERT ALAN, Electrical Draftsman, Pacific Gas & Electric Co.; res., 1125 Ellis St., San Francisco, Calif.

CUDDOHY, JAMES WILLIAM, Meter Superintendent, Consumers Power Company, 129 Pearl St., N. W., Grand Rapids, Mich.

CUMMING, KENNETH NEIL, Assistant Engineer, Radio Corporation of America, Marion, Mass.

DAVIS, JOHN E., Electrical Testman, Duquesne Light Company, 3708-5th Ave., Pittsburgh, Pa.

DELANY, JAMES HENRY, Industrial Engineering; res., 167 Scotland Road, S. Orange, N. J.

de NAGY, ERVIN A., Electrical & Mechanical Designer, Wilson Welder & Metals Co.; res., 75 Sherman Ave., New York, N. Y.

*DeSELLEM, GEORGE WESLEY, Supply Salesman, Westinghouse Electric & Mfg. Co., Portland, Ore.

DIAMOND, HARRY, 126 Water St., Quincy, Mass.

DICKINSON, JAMES GILBERT, Engineer, Electric Distribution Dept., The Milwaukee Electric Railway & Light Company; res., 718 Van Buren St., Milwaukee, Wis.

DODDS, WILLIAM CHARLES, Assistant Foreman, System Regulation Section, Duquesne Light Company, 3708-5th Ave., Pittsburgh, Pa.

DOMINGUEZ, RAUL CAMPOS, Engineer, Monterrey Iron & Steel Works; Prof. Elec. National School of Builders, Edifico Banco de Londres, Mexico City, Mex.

*ELLIOTT, JOHN L., Line Maintenance, Mountain States Power Company, Albany; res., Western Club, Corvallis, Ore.

FARGHER, WILLIAM GORDON, Chief Electrician, Shafer Bros. Lumber & Door Company, Montesano, Wash.

FAULKNER, ARTHUR SPENCER, Engineer in charge of Testing Dept., City Electric Light Company, Ltd., Brisbane, Queensland, Aus.

FERNANDO, M. SAVARIMUTHU, Superintendent of Physical Laboratory & Workshops, St. Joseph's College, Trichinopoly, Teppakulam, South India.

FOUST, CHARLES ALLEN, Electrical Engineer, Nichols Copper Company, Laurel Hill; res., 45 Wilton Ave., Glendale, N. Y.

FULCHER, W. H., Electrical Contractor & Dealer, Cape Charles, Va.

FUNSTON, JAMES EDWARD, Substation Survey, Duquesne Light Company, 3708-5th Ave., Pittsburgh, Pa.

GANNETT, ROBERT, Sales Engineer, Mica Insulator Co., 68 Church St., New York; res., 1208 Hudson St., Hoboken, N. J.

GARDNER, ANSON BLAKE, Engineer, Westinghouse Lamp Co., 165 Broadway, New York, N. Y.
GIANGRASSO, JOSEPH VICTOR, Inspector, Western Electric Company, Inc.; res., 233 E. 6th St., New York, N. Y.
GRUPPE, EDWIN AUGUSTUS, Engineer, Industrial Sales Dept., Rochester Gas & Electric Corp.; res., 241 Gregory St., Rochester, N. Y.
HAMMEL, FOWLER; res., 78 Clarkson Ave., Brooklyn, N. Y.
HARADA, KYOSUKE, Professor, Meiji Institute of Technology, Tobata, Japan; 318 Elmwood Ave., Ithaca, N. Y.
*HAYES, RALPH SEVERSON, Electrical Engineer, Bell Telephone Co. of Pennsylvania; res., 602 E. Leverington Ave., Rosborough, Philadelphia, Pa.
HOSEASON, DONALD BRIGHT, Electrical Machine Designer, Metropolitan-Vickers Electric Co., Ltd., Trafford Park, Manchester, Eng.
HYATT, RALPH S., Manager, Cornell Hydroelectric Company, Valentine, Neb.
JOHNSON, WILLARD, Meter Tester, Mountain States Power Company, Albany, Oregon.
JONES, HORACE R. J., Transmission Maintenance Engineer, The Pacific Tel. & Tel. Co.; res., 1050 S. Bonnie Brae St., Los Angeles, Calif.
KATAYAMA, KAZUO, Electrical Engineer, Takata & Company, 50 Church St., New York, N. Y.
KEMP, PHILIP, Head of Electrical Engineering Dept., The Polytechnic, Regent St., London, W. 1, Eng.
KING, WILLIAM CHARLES, Power Salesman, Bureau of Power & Light, City of Los Angeles; res., 1207 N. Columbus Ave., Glendale, Calif.
LAWRENCE, THOMAS HENRY, Load Dispatcher, Homestake Mining Company, Lead, S. Dakota.
LEDFORD, HARRIS A., Instructor, Automotive Electrical Dept., Harrisburg Mechanical School; res., 1516 Berry St., Harrisburg, Penn.
LOWELL, DWIGHT EVERARD, Engineer of Foreign Wires, Bell Telephone Company of Pa., 261 N. Broad St., Philadelphia, Pa.
MACMILLAN, LAWRENCE C., Assistant Electrical Engineer, Frank F. Fowle & Company, 1201 Monadnock Block, Chicago, Ill.
MANGIONE, JOHN, Inspector, Western Electric Co., 24 Walker St.; res., 800 E. 233rd St., New York, N. Y.
MANNY, HENRY H., Manager, Baker-Joslyn Company, 2424-1st Ave., South, Seattle, Wash.
MASSEY, BEN RAMSEY, Testing Dept., Westinghouse Electric & Mfg. Co., 253 Braddock Ave., Turtle Creek, Pa.
MATTHEWS, WILLIAM H., Assistant Professor of Electrical Engineering, Kansas Manual Training & Normal School; res., 124 E. 22nd St., Pittsburgh, Kansas.
McCUE, RUSSELL, Elec. Const. Man, United Electric Light & Power Co., 416 W. 215th St., New York, N. Y.
McGORMAN, SAMUEL ERNEST, Sales Engineer, Canadian Bridge Company, Walkerville, Ont.
McNEE, ELDON ROBERT, Western Electric Company, Hawthorne Station, Chicago, Ill.
MILLER, JAMES H., Draftsman, McClellan & Junkersfeld, Inc., 45 William St., New York, N. Y.
MITCHELL, JOHN HENRY, Electrical Surveyor, British Engine, Boiler & Electrical Insurance Company, Ltd.; res., 32 Plane St., Hull, Eng.
MOLLERHOJ, JOHANNES SORENSEN, Chief Electrical Engineer, Nordiske Kabel & Traadfabriker, Fabrikvej 23, Copenhagen F, Denmark.
MOORE, LAWRENCE NEWTON, Electrician, Electric Power Equipment Company, 51 E. Chestnut St.; res., 1231 Franklin Ave., Columbus, Ohio.
NAGASHIMA, YASUNOSUKE, Electrical Engineer, The Hayakawa Electric Power Company, No. 60 Tenmacho, Hamamatsu City, Shizuoka-ken, Japan.
NEWMAN, HORACE SIDNEY, Departmental Manager, Bullers Limited, Hanley, Stoke-on-Trent, Eng.
O'BRIEN, LAWRENCE J., Master Sergeant, Signal Corps, U. S. A., Columbus Barracks, Ohio.
OLSON, HARRY J., Instructor to Foreman, Western Electric Co., Kungl Telegrafstyrelsen Sibyllegatan 39, Stockholm, Sweden.
O'NEILL, CHARLES, Electrical Engineer, Westend Chemical Company, Las Vegas, Nevada.
ONETO, WASHINGTON, Electrical Designer, The Philadelphia Electric Company, 10th & Chestnut Sts., Philadelphia, Pa.
*OSTERLE, WILLIAM HENRY, Engineer, The Charles M. Kelso Company, Dayton; res., 215 W. 2nd St., Xenia, Ohio.
PARKER, MERTON C., Electrical Installation; res., 882 E. Ash St., Portland, Ore.
PEAK, EARL NELSON, President & General Manager, Marshall Electric Company, Inc., 1603 W. Main St., Marshalltown, Iowa.
PEARCE, STANLEY BANKS, Assistant Chief Draftsman, Commonwealth Naval Dockyard, Cockatoo Island; res., "Tybridge," Woolwich Road, Woolwich, Sydney, N. S. W.
PEARL, EUGENE SHERWOOD, Sales Department, Radio Corporation of America, 233 Broadway, New York, N. Y.; res., 307 Gregory Ave., Passaic, N. J.
PICKARD, EDWARD ETHEGELBERT, Electrical Draftsman, Electric Storage Battery Co.; res., 2218 W. Allegheny Ave., Philadelphia, Pa.
PRICE, DON, Instructor, Electrical Engineering, Lafayette College, Easton, Pa.; res., 56 E. Main St., Norwich, N. Y.
PRICE, ROBERT B., Salesman, Duplex Lighting Works of General Electric Company, 6 W. 48th St., New York, N. Y.
QUANTRILLE, CLINTON ASPELL, Load Dispatcher, Low Tension System, Potomac Electric Power Company; res., 115th E. St., S. E., Washington, D. C.
QVIST, OSCAR, Engineering Draftsman, Commonwealth Edison Company; res., 2953 Fullerton Ave., Chicago, Ill.
RACAJ, JOSE AQUILES, Operating Engineer, Power Plant, International Paper Co., Wilder, Vt.
RAMSEY, MARION AMBROSE, Educational Dept., Westinghouse Elec. & Mfg. Co., E. Pittsburgh; res., 107 Brown Ave., Turtle Creek, Pa.
REID, HARRY, President, Kentucky Utilities Co., Louisville, Ky.; Interstate Public Service Co., 510 Board of Trade, Indianapolis, Ind.
ReQUA, WILLIAM A., President, ReQua Electrical Supply Co., 95 St. Paul St., Rochester, N. Y.
*RISK, GEORGE, Jr., Telephone Engineer, American Tel. & Tel. Company, 195 Broadway, New York, N. Y.
RIVERS, FABIAN N., Long Lines Engineering Dept., American Tel. & Tel. Co., 195 Broadway, New York, N. Y.
ROACH, FRED J., Sales Engineer, De Forest Radio Tel. & Tel. Company, Central Ave., & Franklin St., Jersey City, N. J.; res., 2973 Bainbridge Ave., New York, N. Y.
ROCCA, WILLIAM SALVATORE, Electrical Contractor, 42-22nd St.; res., 781 Lincoln Place, West New York, N. J.
RODEY, BERNARD SHANDON, Jr., Engineering Accountant, Valuation Bureau, United Electric Light & Power Company, New York, N. Y.; res., 61 Church St., Montclair, N. J.
RODRIGUEZ, JUAN M., Westinghouse Electric International Company; res., Plaza Vizcainas No. 1, Mexico, D. F., Mex.
SAWYER, CHARLES N., Major, Signal Corps, Camp Alfred Vail, N. J.
SCANNELL, HORATIO C., Electrical Contractor, 709 Adams St., Toledo, Ohio.
SCHEEL, ALFRED A., Manager, Lee Electric Company, Corning, Iowa.
SCOTT, LESTER FRANCIS, Salesman, U. S. Electrical Mfg. Company, 300 Central Ave., Los Angeles; res., 1431-15th St., Sacramento, Calif.
SHARP, CECIL BIGBIE, Sub-Foreman, System Regulation Dept., Duquesne Light Company; res., 3443 Dawson St., Oakland, Pittsburgh, Pa.
SINNOTT, JOSEPH DANIEL, Sales Engineer, Westinghouse Electric & Mfg. Co., Spokane, Wash.
SMITH, KYLE, Electrical Designer, Perin & Marshall, 1107 Broadway, New York; res., 1819 Beverly Road, Brooklyn, N. Y.
SMITH, LYLE WESLEY, Lighting Engineering Dept., General Electric Co., Schenectady, N. Y.
SMITH, MYRON HOWE, Engineer, Western Electric Co., 463 West St., New York, N. Y.
SOLDINI, MARIO GIUSEPPE, res., 37A, Foro Bonaparte, Milan 9, Italy; International General Electric Co., Schenectady, N. Y.
STEINHOFF, HORACE WOLLFKIN, Inspector, Western Electric Company, 463 West St., New York; Central Branch, Y. M. C. A., Brooklyn, N. Y.
STRONG, THOMAS FOSTER, Hydroelectric Plant Operator, Utah Power & Light Company, Oneida Station, Preston, Idaho.
TAKAI, RYOTARO, Designer, Electrical Dept., Inawashiro Hydroelectric Power Co., Marunouchi, Toyko, Japan.
TAYLOR, WILLIAM HERBERT, Operator, United Traction Company, Albany; res., 1008-2nd Ave., N. Troy, N. Y.
*THAYER, ALFRED H., Student, Stanford University, Upland, Calif.
TSUTSUMI, ISAMU, Electrical Engineer, Takata & Company, 50 Church St., New York, N. Y.
TUFTS, BOWEN, Vice-President, C. D. Parker & Company, 150 Congress St., Boston, Mass.
TURNBULL, W. GORDON, Works Manager & Chief Engineer, Turnbull Elevator Company, Ltd., 126 John St., Toronto, Ont.
VAUGHAN, GEORGE W., Teacher, Elec. Engg. Dept., Trinity College, Durham, N. C.; Huntington, N. Y.
WALDMANN, CHARLES, C. B. Comstock, 110 W. 40th St., New York, N. Y.
*WALKER, HARRY WADE, Leading Electrician, Watkinson & Kennett, 263 Taum St.; res., 42 Cowlishaw St., Avonside, Christchurch N. Z.
WARNER, MUNROE FRANK, Chief Engineer, American Zinc & Chemical Co., Langeloth, Pa.
WELSFORD, DOUGLAS, Senior Operator, North Metropolitan Electric Power Supply Company; res., 43, Princess Road, Kilburn Park, London, N. W. 6, Eng.
WESTCOTT, PHILIP S., Asst. Car Lighting Engineer, Chicago, Milwaukee & St. Paul Railway Co., Milwaukee Shops, Wis.
WINTER, MARVIN M., 162 Beach 26th St., Far Rockaway, N. Y.
YOSHIDA, REIJI, Electrical Engineer, Daido Electric Power Company, Nagoya, Japan.

Total 127.

*Formerly Enrolled Students.

ASSOCIATES REELECTED OCTOBER 9, 1922

COLLINS, JOSEPH F., Secretary & Chief Engineer, Mitten-Traylor, Inc., 1108 Land Title Bldg., Philadelphia, Pa.
CONKLING, deWITT C., Vice-President Chief Engineer, Pioneer Engineering Corp., 395 Broadway, New York; res., 122 21st Street, Elmhurst, N. Y.

HOUGHTON, ALBIN J., Jr., Electrical Draftsman, Southern California Edison Co., 1201 W. 2nd St., Los Angeles, Calif.

SKACELIK, JOSEPH, Electrical Engineer Central Electrical Works, Trida Svornosti 1372, Prague-Smichov, Bohemia.

ASSOCIATE REINSTATED OCTOBER 9, 1922

GORHAM, C. FRED, Chief Draftsman & Designing Engineer, Hydroelectric Power Commission of Ontario; res., 67 Berwick Ave., Toronto, Ontario.

MEMBERS REELECTED OCTOBER 9, 1922

HUNT, WILLIAM VALENTINE, Consulting Engineer, 198 Hastings St., Vancouver, B. C.

THULLEN, L. H., 7 East 42nd Street, New York, N. Y.

MEMBER REINSTATED OCTOBER 9, 1922

PECK, LOUIS T., Managing Director, Compania Westinghouse Electric Internacional, Avenida de Mayo 1035, Buenos Aires, Argentine, S. A.

MEMBERS ELECTED OCTOBER 9, 1922

CANIVET, JEAN, Resident Engineer, Representing the Campagnie Francaise; International General Electric Company, Schenectady, N. Y.

CRAFT, WARREN MOORE, Dept. of Operation & Engineering, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

GREEN, KENNETH F., Superintendent, Wisconsin River Power Company, Prairie de Sac, Wis.

HARTMANN, JULIUS F. G. P., Chief of The Hartmann Rectifier Company; Den Polytekniske Laereanstall, Solvgade, Copenhagen, Denmark.

McFARLAND, HUGH BARCLAY, President & Treasurer, Lennox Milling Company, Lennox, S. Dak.

PATTERSON, ALBERT B., General Superintendent, Railway Dept., New Orleans Railway & Light Co., New Orleans, La.

WEBBE, HAROLD WILLIAM, Captain Signal Corps, U. S. A.; Professor Military Science & Tactics, Ohio State University, Columbus, Ohio.

FELLOW ELECTED OCTOBER 9, 1922

NISSEN, JACOB PREBENSEN, Consulting Electrical Engineer, Nissen og von Krogh Pronprinsens gate 3, Kristiania, Norway.

TRANSFERRED TO GRADE OF MEMBER OCTOBER 9, 1922

BADGER, CHARLES K., Chief Engineer, Empresa Electrica de Guatemala, Gerente Empresa del Alumbrado Electrico del Norte, Guatemala City, Guatemala, C. A.

BISHOP, WILLIS D., Sales Manager, Power Switchboard Division, Northern Electric Co., Ltd., Montreal, Canada.

CANN, JOHN O. G., Chief Engineer, Marconi Wireless Tel. Co. of Canada, Ltd., Montreal, Canada.

DIXON, AMOS F., Telephone Systems Engineer, Western Electric Co., New York, N. Y.

GODSHO, ALBERT P., Assistant Engineer, Bel. Telephone Co., of Penna., Philadelphia, Pal

KELLY, JOHN A., Chief Engineer, Elec. Construction Dept., Dingle Clark Co., Cleveland, Ohio.

LOVELL, WILLIAM V., Assistant Engineer, National Electric Light Ass'n., New York, N. Y.

MAHONEY, FRANCIS W., Electrical Engineer, Densmore & LeClear, Boston, Mass.

ROFFEY, MYLES H., Professor in Charge of Electrical Department, Hongkong University, Hongkong, China.

ROSE, ARTHUR F., Electrical Engineer, American Tel. & Tel. Co., New York, N. Y.

WOODBURY, FRED P., Meter & Test Dept., United Electric Light & Power Co., New York, N. Y.

TRANSFERRED TO GRADE OF FELLOW OCTOBER 9, 1922

CRAWFORD, MAGNUS T., Supt. of Distribution, Puget Sound Power & Light Co., Seattle, Wash.

WEBER, CLIFFORD A. M., Engineer in General Charge, Small Motor Engineering Dept., Westinghouse Electric & Mfg. Co., Springfield, Mass.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held October 2, 1922, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Fellow

MITCHELL, WILLIAM E., Assistant General Manager, Alabama Power Co., Birmingham, Ala.

To Grade of Member

BLAISDELL, LEONARD T., Local Manager, General Electric Co., Washington, D. C.

CARLTON, H. E., Chief Electrical Engineer, Virginia Iron, Coal & Coke Co., Toms Creek, Va.

COLEMAN, RAYMOND M., Manager, Electrical Department, Fairbanks Morse & Co., New York, N. Y.

GURDES, FRED A., Electrical Layout Engineer, with C. H. Shepherd, Chicago, Ill.

LINCOLN, E. S., President, E. S. Lincoln, Inc., Portland, Me.

OBERMAIER, JOHN A., Engineer in Charge, Illinois Testing Laboratories, Inc., Chicago, Ill.

RANSOM, LEWIS L., Vice-President & Treasurer, Ransom & Anderson Co., Inc., Jersey City, N. J.

STEINBACH, EDWARD S., Mechanical Engineer, Stone & Webster, Inc., Boston, Mass.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before November 30, 1922.

Akdins, Keller W., Kansas City, Mo.
Anderson, F. Paul, Jr., Irvington, N. J.
Archer, Luther B., Urbana, Ill.
Atherton, Howard L., Betsy Layne, Ky.
Bailey, Eugene S., Baltimore, Md.
Barnes, Lloyd A., Los Alamitos, Calif.
Beck, Wilbur A., Bethlehem, Pa.
Beuderoth, Edison T., St. Louis, Mo.
Bolles, Carleton Francis, Newark, N. J.
Bowman, N. Floyd, Baltimore, Md.
Brown, G. Carlton, Cincinnati, Ohio
Campbell, Seth E., Lynn, Mass.
Carter, James R., Boston, Mass.
Charleson, Edward V., Woodville, Pa.
Chavannes, Albert L., Urbana, Ill.
Cummins, P. Richard, Camden, N. J.
Cunningham, Harry V., E. Boston, Mass.
Dachner, Richard H., San Francisco, Calif.
Dean, Samuel W., Lexington, Mass.
Deats, Charles T., Flemington, N. J.
DeBear, Alvin C., New York, N. Y.
Dember, David, Brooklyn, N. Y.
Doub, Cyrus L., E. Pittsburgh, Pa.
Enfield, Ernest E., Toronto, Ont.
Foley, James D., Pittsburgh, Pa.
Frank, William H., Newark, N. J.
French, Joseph A., (Member), Norwich, Conn.
Freshman, Fred G., Kansas City, Mo.
Fuld, Sidney, New York, N. Y.
Genrich, Herman C., Cincinnati, Ohio
Graff, James McN., Baltimore, Md.
Greef, Max., New York, N. Y.
Harrison, Joseph M., Baltimore, Md.
Hendry, Charles M., New York, N. Y.
Henninger, G. Ross, E. Pittsburgh, Pa.
Henningsen, Glenn L., Omaha, Neb.
Hopkins, Robert H., New York, N. Y.
Hornor, Harry H., Danville, Ill.
Hughes, David M., Trenton, N. J.
Kester, Allen J., Akron, Ohio
King, Mathew, New York, N. Y.
LaCasse, Joseph A., Pittsfield, Mass.
Mackin, John 3rd, Philadelphia, Pa.
Matthews, Ralph G., Toronto, Ont.
McClurken, Raymond W., Philadelphia, Pa.
Meredith, Clive B., Cazenovia, N. Y.
Miller, J. Bryan, Electra, Texas
Millikan, Robert A., (Member), Pasadena, Calif.
Moore, Charles W., Detroit, Mich.
Morehouse, H. Preston, Sharon, Conn.
Nordholm, A. G., Yonkers, N. Y.
Nyswander, Reuben E., (Member), Denver, Colo.
O'Neill, Herbert Addison, Chicago, Ill.
Pearson, George H., Montreal, Que.
Perkins, Howard L., New York, N. Y.
Price, Heath, New York, N. Y.
Rah, Joseph, Chicago, Ill.
Ridout, Percy, New York, N. Y.
Rowe, George H., (Member), Los Angeles, Calif.
Scutt, George W., Philadelphia, Pa.
Small, William, Philadelphia, Pa.
Smith, Frederick A., Glace Bay, N. S.
Smith, Louis G., Baltimore, Md.
Snyder, William J., Atlantic City, N. J.
Stollmack, Richard, Brooklyn, N. Y.
Storrs, Lucius S., New Haven, Conn.
Strand, Gilbert H., San Diego, Calif.
Stringfellow, George E., Washington, D. C.
Stripp, John E., Framingham, Mass.
Thomas, David R., Washington, D. C.
Thone, John F., Boston, Mass.
Trowbridge, Eugene L., Denver, Colo.
Walker, John D., Swissvale, Pa.
Wasserman, Harry, Brooklyn, N. Y.
Woodbury, David O., San Francisco, Calif.
Zimmerman, Clarence LeR., Chicago, Ill.

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Foreign

Cannock, Richard H. I., Lima, Peru
Contesi, J. Emilio, (Member), Guatemala City, C. A.
Hersam, Eugene C., Kahuku, Oahu, T. H.
Matsuki, Sadaki, Kurosaki-machi, Fukuoka-ken, Japan

Total 4

STUDENTS ENROLLED OCTOBER 9, 1922

15330 Cook, Dean C., Tri-State College of Engineering
15331 Cushing, Levi G., Northeastern College
15332 Samson, David F., New York Electrical School
15333 Ruppell, Edward A. H., New York Electrical School
15334 Moore, George E., New York Electrical School
15335 Eder, Harold H., Massachusetts Institute of Technology
15336 McCarville, William A., Marquette University
15337 Strong, Everett M., Massachusetts Institute of Technology
15338 Watchorn, Carl W., Worcester Polytechnic Institute
15339 Ganey, Leo T., Wentworth Institute
15340 Serentio, James A., New York Electrical School
15341 Gurtler, Hugo O., Jr., New York Electrical School
15342 Beaulieu, Gerard, New York Electrical School
15343 Layton, Edgar N., California Institute of Technology
15344 Sugarman, Frank L., New York Electrical School
15345 Rehm, William P., New York Electrical School
15346 Natoli, Dominic, New York Electrical School
15347 Kitts, Wesley B., University of California
15348 Byrne, Hugh P., University of California
15349 Oliver, Cuthbert J., McGill University
15350 Flohr, Sheldon Noble, Tri-State College
15351 Godard, George Dewey, Massachusetts Institute of Technology

15352 Nicholson, Kenneth James, New York Electrical School
15353 Canary, John F., New York Electrical School
15354 Born, Edward Oscar, Tri-State College
15355 Klann, Alvin R., University of Wisconsin
15356 Hume, James N., Kansas State Agricultural College
15357 Williams, Francis Reid, Kansas State Agricultural College
15358 Wilson, M. R., Kansas State Agricultural College
15359 Henderson, Iliff Lowell, Okla. Agri. & Mech. College
15360 Pratt, Elbert Harold, Okla. Agri. & Mech. College
15361 Atkinson, Roy C., Okla. Agri. & Mech. College
15362 Box, Carl L., Okla. Agri. & Mech. College
15363 Hahn, William Clingman, Massachusetts Institute of Tech.
15364 Woodward, John Eggleston, Virginia Military Institute
15365 Foster, Sidney Parks, Virginia Military Institute
15366 Coleman, Solon Bernard, Virginia Military Institute
15367 Thompson, Ester Carter, Virginia Military Institute
15368 Gatewood, Richard Loren, Virginia Military Institute
15369 Girand, James, Virginia Military Institute
15370 Royal, Albert Booth, Marquette University
15371 Pretlow, Robert H., Jr., Virginia Military Institute
15372 Thornton, B. N., Virginia Military Institute
15373 Johnson, Charles A., Jr., Virginia Military Institute
15374 Jones, Frederick W., Virginia Military Institute
15375 Meserve, Wilbur E., University of Maine
15376 Lappin, Chase R., University of Maine
15377 Cyphers, Kenneth L., University of Maine
15378 Dowling, Roy C., University of Wisconsin
15379 Davenport, Junius C., Jr., Virginia Military Institute
15380 Cooke, Stockton, Jr., Virginia Military Institute
15381 Koeton, T. E., Agricultural & Mechanical College of Texas
15382 Cocherell, Fred., Kansas State Agricultural College
15383 Know,esl Carl L., Kansas State Agricultural College
15384 Flynn, Joseph B., Kansas State Agricultural College
15385 Barton, Gerald D., Kansas State Agricultural College
15386 Weybrew, Thelbert L., Kansas State Agricultural College
15387 Low, Herbert M., Kansas State Agricultural College
15388 Chase, Ralph E., Kansas State Agricultural College
15389 Bradshaw, Chester L., Kansas State Agricultural College
15390 Buck, Guy Emerson, Kansas State Agricultural College
15391 Hartman, Hugh E., Kansas State Agricultural College
15392 Swim, H. A., Kansas State Agricultural College
15393 De Tar, Donald R., Kansas State Agricultural College
15394 Rose, Herbert A., Kansas State Agricultural College
15395 Gibbon, Clark K., Kansas State Agricultural College
15396 Swarner, J. Frank, Kansas State Agricultural College
15397 Leonard, James M., Kansas State Agricultural College
15398 Moore, Wesley R., Drexel Institute
15399 Krueger, Raymond A., University of Wisconsin

Total 70

OFFICERS OF A. I. E. E. 1922-1923

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(A list of the personnel of Institute committees may be found in the September issue of the Journal. Will be reprinted in the January Journal.)

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Membership, R. B. Howland
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Instruments and Measurement, G. A. Sawin
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Marine, G. A. Pierce, Jr.
Mines, Graham Bright
Power Stations, Nicholas Stahl
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Traction and Transportation,
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American Committee on Electrolysis
American Engineering Council of the Federated American Engineering Societies
American Engineering Standards Committee
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Providence	R. W. Adams	F. N. Tompkins, Brown University, Providence, R. I.
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Seattle	W. D. Scott	E. S. Code, 3451 E. Margina Way, Seattle, Wash.
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Syracuse	R. D. Whitney	Elmer E. Strong, 615 City Bank Bldg., Syracuse, N. Y.
Toledo	Gilbert Southern	Max Neuber, 1257 Fernwood Ave., Toledo, O.
Toronto	S. E. M. Henderson	D. B. Fleming, Hydro-Elec. Pr. Comm., 190 University Ave., Toronto, Ont.
Urbana	H. A. Brown	E. B. Paine, University of Illinois, Urbana, Ill.
Utah	C. C. Pratt	C. R. Higson, Utah Pr. & Lt. Co., Salt Lake City, Utah
Vancouver	T. H. Crosby	F. W. MacNeill, Canadian General Elec. Co., Vancouver, B. C.
Washington, D. C.	L. T. Blaisdell	Roland Whitehurst, Elec. Storage Battery Co., 1823-33 L. St. N. W., Washington, D. C.
Worcester	F. J. Adams	Dean J. Locke, 125 Salisbury St., Worcester, Mass.

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Alabama Univ. of, University, Ala.	D. H. Davis	W. W. Bauder
Arizona, Univ. of, Tucson, Ariz.	R. A. Macdonald	H. A. Hillman
Arkansas Univ. of, Fayetteville, Ark.	L. G. Huggins	E. J. Anderson
Armour Inst. of Tech., Chicago, Ill.	L. E. Grube	H. M. Piety
Brooklyn Poly. Inst., Brooklyn, N. Y.	A. E. Shaw	H. B. Hanstein
Bucknell Univ., Lewisburg, Pa.	F. T. Tingley	J. A. Ammerman
California Inst. of Tech., Pasadena, Cal.	O. R. Bulkley	L. J. Wells
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Colorado, Univ. of, Boulder, Colo.	G. H. Dewey	R. H. Owen
Cooper Union, New York	W. A. Colledge	A. L. Duna
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Georgia School of Tech., Atlanta, Ga.	J. L. Torbett	F. R. McClellan
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Kansas State College, Manhattan, Kans.	L. O. Sinderson	K. C. Frank
Kansas, Univ. of, Lawrence, Kans.	D. Eyer	Wm. Anderson
Kentucky, Univ. of, Lexington, Ky.	T. M. Riley	R. H. Craig
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Lehigh Univ., South Bethlehem, Pa.	E. H. Snyder	R. W. Barrell
Lewis Institute, Chicago, Ill.	E. Millison	E. R. Lindberg
Maine, Univ. of, Orono, Me.	C. R. Lappin	H. L. Durgin
Marquette University, Milwaukee, Wis.	G. E. Phelps	P. P. Stathas
Massachusetts Inst. of Tech., Cambridge, Mass.	E. J. Thimmie	H. D. McKinnon
Michigan Agri. Coll., East Lansing, Mich.	E. A. Pryce	J. G. Lauffer
Michigan, Univ. of, Ann Arbor, Mich.	R. N. Olds	A. J. Martin
Milwaukee, Engg. School of, Milwaukee, Wis.	M. J. Maiers	J. P. Gibbons
Minnesota, Univ. of, Minneapolis, Minn.	R. H. Olson	C. L. Sampson
Missouri, Univ. of, Columbia, Mo	A. C. Lanier	F. W. Hubbard
Montana State Coll., Bozeman, Mont.	R. R. Thomas	J. A. Thaler
Nebraska, Univ. of, Lincoln, Neb.	O. J. Ferguson	O. E. Edison
North Carolina State College, West Raleigh, N. C.	Z. M. Harry	P. M. Sullivan
North Carolina, Univ. of, Chapel Hill, N. C.	W. C. Moore	R. H. Jackson
North Dakota, Univ. of, University, N. D.	C. W. Randall	Byron Hill
Notre Dame, Univ. of, Notre Dame, Ind.	V. J. Brown	W. L. Shilts
Ohio Northern Univ., Ada, O.	D. J. Wolf	H. L. Vincent
Ohio State Univ., Columbus, O.	W. M. Kellogg	O. McGinnis
Oklahoma A. & M. Coll., Stillwater, Okla.	C. S. Folk	I. T. Knight
Oklahoma, Univ. of, Norman, Okla.	Cecil Roush	R. B. Greene
Oregon Agri. Coll., Corvallis, Ore.	J. H. Murton	J. H. Casto
Pennsylvania State College, State College, Pa.	H. T. Axford	D. N. Yoder
Pennsylvania, Univ. of, Philadelphia, Pa.	O. W. Manz, Jr.	A. R. Horner
Pittsburgh, Univ. of, Pittsburgh, Pa.	C. A. Anderson	A. F. Robert
Purdue Univ., Lafayette, Ind.	J. F. Welch	O. T. McIlvaine
Rensselaer Poly. Inst., Troy, N. Y.	W. J. Williams	L. S. Inskip
Rose Poly. Inst., Terre Haute, Ind.	F. M. Stone	C. B. Wilson
Rutgers College, New Brunswick, N. J	C. S. Beattie	E. H. Erickson
Southern California, Univ. of., Los Angeles, Cal.	R. H. Cockfield	E. B. Heath
Stanford Univ., Stanford University, Cal.	H. E. Becker	V. Marquis
Swarthmore Coll., Swarthmore, Pa.	S. T. McAllister	E. Palmer
Syracuse Univ., Syracuse, N. Y.	L. E. Angwin	L. E. Lawrence
Texas A. & M. Coll., College Station, Tex.	T. E. Keeton	R. S. Drake
Texas, Univ. of, Austin, Tex.	C. H. Marshall	F. J. Domingues
Virginia Military Inst., Lexington, Va.	J. Giraud	J. E. Woodward
Virginia Poly. Inst., Blacksburg, Va.	T. F. Cofer	F. L. McClung
Virginia, Univ. of, University, Va.	T. R. Bunting	P. L. Weir
Washington, State Coll. of, Pullman, Wash.	C. R. Studer	E. J. Leahy
Washington Univ., St. Louis, Mo.	F. W. Schramm	E. H. Burgess
Washington, Univ. of, Seattle, Wash.	J. V. Wilson	A. W. Lundstrum
West Virginia Univ., Morgantown, W. Va.	H. Chandler	W. D. Stump
Wisconsin, Univ. of, Madison, Wis.	R. B. Bohman	J. W. Smart
Yale Univ., New Haven, Conn.	J. T. Houk	J. T. Houk

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DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGUES AND OTHER PUBLICATIONS

Mailed to interested readers by issuing companies.

Automatic Stoker.—Bulletin CB 1, 24 pp. Describes the operation of the Coxe stoker and includes performance data. Combustion Engineering Corporation, Broad Street, New York.

Oil Refinery Apparatus.—Bulletin 910, 8 pp. Describes coolers, exchangers and condensers for oil refineries. The Griscom-Russell Company, 90 West Street, New York.

Motors.—Booklet, 32 pp. Describes fifty different applications of fractional horse-power motors and tests for determining the suitability of each type. Bodine Electric Company, Chicago.

Resistance Measuring Instrument.—Bulletin 115. Describes the "Standco" megohmer, Model D, for measuring and testing voltages. Herman H. Sticht & Company, 15 Park Row, New York.

Linemen's Tools.—Bulletin. Describes rubber insulated safety tools for use on high tension lines and electrical machinery. Rubber Insulated Metals Corporation, 50 Church Street, New York.

Specifications for Copper Clad Wire.—Folder. Describes standard specifications for purchase, inspection and testing of "Copperweld" wire. The Copper Clad Steel Company, Rankin, Pa.

Steam Turbines.—"Construction of a Steam Turbine Wheel." An illustrated article describing the factors to be considered in building steam turbine wheels. Moore Steam Turbine Corporation, Wellsville, N. Y.

Demand Meter.—Bulletin 46108. Describes type M-4 demand meter for use in conjunction with a watthour meter to indicate maximum demand. General Electric Company, Schenectady, N. Y.

Precision Measuring Instruments.—Folder, 8 pp. Describes the "Minimeter," an instrument for measurements up to 1/10,000 of an inch in the manufacture of machine parts. The Norma Company of America, Long Island City, N. Y.

Brush Chart.—A chart showing causes and effects of carbon brush and commutator troubles. The chart is in such form that it will be of great assistance in locating and correcting troubles on direct-current motors and generators. The Martindale Electric Company, 11717 Detroit Ave., Cleveland.

Motor and Power Transmission Anchorages.—Bulletin, 16 pp. Describes a line of box rails and steel sections for the anchorage of motors and transmission apparatus to ceilings, floors or side walls. Midwest Steel & Supply Company, 28 West 44th Street, New York.

Motors.—Bulletin 28, 24 pp., Automatic Start Induction Polyphase Motors; Bulletin 29, 32 pp., Repulsion Start Induction Single Phase Motors; Bulletin 30, 16 pp., Squirrel Cage Induction Polyphase Motors; Bulletin 31, 16 pp., Split Phase Induction Motors. Century Electric Co., St. Louis.

Heat Treatment in Industry.—Bulletin, 44 pp., "Elements of Industrial Heating." Outlines the principles governing the heat treatment of metallurgical, chemical and ceramic products, and the selection and use of equipment, fuel or electricity. W. S. Rockwell Company, 50 Church Street, New York.

Electric Railway Supplies.—Catalog, 32 pp. Describes railway equipment such as trolley wheels, poles, bearings, gear cases, castings, armature coils, commutators, jacks, car hoists, winding and taping machines, etc. Columbia Machine Works and Malleable Iron Company, 3333 Atlantic Avenue, Brooklyn, N. Y.

Radio Antenna Plug.—A report of the Underwriters' Laboratories, Chicago, on the radio antenna plug known as the Dubilier "Ducon," a device in the form of an attachment plug designed to be attached to an ordinary lighting socket for the utilization of the electric wiring system as an antenna. The Dubilier Condenser & Radio Corporation, 48 West 4th Street, New York.

Modern School Lighting.—Bulletin 344, 36 pp. Gives general information regarding school lighting and contains complete tables of utilization constants for all conditions of room size and decorations. A simple form of reflectometer is included so that the reflection factor of paints ordinarily used for ceilings and walls in school buildings can be easily determined. The Holophane Glass Co., 342 Madison Ave., New York.

Link-Belt Company, Chicago.—General catalog No. 400, cloth bound, 832 pp. A comprehensive description of Link-Belt products, among which may be mentioned chains and wheels, boiler plant equipment, including crushers, feeders and water screens; power transmission machinery, including bearings, hangers, gears, clutches, pulleys; conveying equipment; electric hoists, overhead cranes, power shovels; coal storage equipment; car loaders. A copy of the catalog may be obtained from any branch office of the company.

NOTES OF THE INDUSTRY

Lapp Insulator Company, Inc., LeRoy, N. Y.—The O. H. Davidson Equipment Company, Denver, Colo., has been appointed representative for Utah, Colorado, southern Wyoming and northern New Mexico.

Ohio Electric & Controller Company, Cleveland.—Mark C. Smith, formerly of the Westinghouse Electric & Mfg. Company, has been appointed Chicago district sales manager of the Motor Department, with offices at 53 West Jackson Boulevard.

Westinghouse Electric & Mfg. Company, East Pittsburgh.—Announcement is made of the transfer of the Krantz Works of the Westinghouse Company from Brooklyn, N. Y., to Mansfield, Ohio. The change was made necessary on account of increased production and the need for more adequate facilities.

The Norma Company of America, Long Island City, N.Y.—The American patents and business of the Hoffman Manufacturing Company, of Chelmsford, Essex, England, makers of the Hoffman roller, ball and thrust bearings, has been acquired by the Norma Company, and the line of the "Norma" precision ball bearings will now be supplemented with the Hoffman precision roller bearings and other bearings in the Hoffman line. The Norma Company will erect a new plant for the manufacture of Hoffman products in America, and in the meantime they are being imported and sold under the regular Norma engineering service.

The Johns-Pratt Company, Hartford, Conn.—Noark fuses and protective devices, Vulcabeston packing and insulation, and molded products. Announcement is made of the appointment of Geo. V. W. Ingham as eastern sales manager for the Electrical Division, with headquarters at the New York office of the company in the Liggett Building, 41 East 42nd Street. Mr. Ingham until recently held the position of eastern sales representative of The Bryant Electric Company, with whom he was associated for eleven years.

Mr. Geo. W. Mapother has been appointed New York district sales manager for the Electrical Division, with headquarters at the New York office of the company.

Foote Bros. Gear & Machine Company, Chicago.—John B. Foote, pioneer gear maker, and president of the Foote Bros. Company, died in Chicago, October 12. He was one of the first to invent and build enclosed types of transmission for reducing electric motor speed. He was also a pioneer in the farm tractor field; an inventor of numerous automatic machines, and was regarded as a foremost authority on special machinery. The business of the firm, which he founded, will be continued by his widow, Aimee W. Foote, and his brother, Bradford Foote.